SENSOR PROTOTYPE FOR CHECKERBOARD VISUAL EVOKED POTENTIALS

ANDREA LISETH ACOSTA ESQUIVEL

MASTER IN ENGINEERING AND INNOVATION MANAGEMENT
FACULTY OF ENGINEERING
UNIVERSIDAD CATÓLICA DE COLOMBIA & UNIVERSIDAD DE SALERNO
BOGOTÁ, JUNE 2020

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ANDREA LISETH ACOSTA ESQUIVEL

Universidad Católica Advisor: HOLMAN DIEGO BOLÍVAR BARÓN

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BOGOTÁ, JUNE 2020

ACCEPTANCE NOTE

Jury

Jury

Holman Diego Bolivar Barón, Ph.D
Advisor

Bogotá, JUNE, 2020

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ABSTRACT

Over the years, technological developments have been analyzed in depth to study and understand the behavior of the human nervous system. Encephalographic systems have been developed in order to study the electrical pulses that are generated through nerve transmitters and to analyze the electrical information that is generated by them. Although extensive progress has been made in the capture and sampling systems for this type of signal, these systems are very complex and invasive, apart from being very expensive and requiring extensive time frames and controls to be able to correctly process the acquired signals.

This project presents the development of an encephalographic signal capture system based on the design of analog-digital circuits and digital sampling systems for checkerboard visual evoked potentials.

By using dry electrodes placed at key capture points, the capture of encephalographic signals is performed to be amplified and filtered by means of analog operational amplifiers, which by means of electrical designs were used as electrical processing systems, eliminating the presence of external signals known as noise. Once the specific signals are obtained, a digital capture and processing process is carried out through data acquisition cards and digital processing software that allowed the sampling of the captured signals, converting the analog signals into digital signals, so that the behavior of each type of signal can be processed and analyzed in a more simplified and controlled way.

Through the processing of the waves, four standard waves known as Beta, Alpha, Theta and Delta were exalted. These working at their own frequencies and allowing the analysis of the pulses generated from various stimuli. For the project worked, a system of visual evokes based on a chessboard was proposed, that presents variations in position and frequency to stimulate the pulses generated by the nervous system.

With the processing and storage of the data recorded during the visual stimulation tests, an optimal wave analysis system was obtained, with the ability to closely record complex systems with an average difference of 0.14469253 in amplitude for standardized signals, showing a very acceptable behavior for a low cost capture system and easy acquisition

Key Words: Encephalogram, encephalographic systems, signal capture and sampling systems, analog-digital processing, visual evoked systems, signal processing.

1. INTRODUCTION

Electrical signal reading devices have been developed in different technological and industrial areas for the ability to give information by reading and translating electrical information in human-readable terms. Different reading and diagnostic equipment based on the electrical signal reading systems have been implemented in health systems, providing information about the human body.

The most complex reading systems are those that work through the interpretation of very low signals, in electrical terms they are those that handle ranges of microvolts and millivolts. Many of these systems in the health area are used in the reading of internal signals from the body such as electrocardiographic signals, electroencephalographic and electromyography signals, which are generated by the stimuli and signals transmitted by the nervous system throughout the body.

The electrical signal reading systems are widely used for testing, diagnosing and stopping diseases for different cases. Through the analysis of signals and waves, these systems can give information about the internal functioning of the people treated, identifying ranges, variations and anomalies that can occur in the electrical information acquired from people, and that would indicate a malfunction of the internal systems.

Diagnostics based on the reading of encephalographic signals are among the most complex due to the large amount of information that this transmitted, in addition to being the most complicated to capture due to the different layers of bone, muscle and skin that protect the brain, which is the area of interest. Many systems have developed techniques that facilitate access and reading of the electrical signals provided by the brain, but many of these are based on invasive systems that affect the comfort of patients, either physically or psychologically.

Many of the encephalographic signal reading systems are complex systems, composed of various components that allow the reading of the signals of interest. Due to the fact that the information handled is made up of various ranges of signals, in addition to the interference of external signals such as heart palpitation, electrical/digital components must be used to reduce or eliminate external signals in the reading information. Signal cleaning systems are known as filters, these allow the passage of signal waves between different frequency ranges so that these attenuate the signals and transmit the information in the control ranges with which these have been designed.

Signal processing is a complex process based on the digitization of analog signals, to be taken to reading and sampling systems that allow the captured information to be observed. The data acquisition systems allow obtaining, storing and transmitting the information captured by analog sensors; The analog-digital conversion is based on the Fourier formula, which allows analog signals to be brought to discrete data that can be handled by digital systems. To achieve the sampling of encephalographic signals is necessary to use data acquisition systems that can transmit the signals to digital systems, in which all the acquired information can be read and interpreted.

With the use of data reading and visualization systems, different techniques have emerged to carry out diagnostic tests that allow determining anomalies or failures of the human body. Through the acquisition, reading and sampling of encephalographic signals, operating ranges have been given for the different signals generated; The presence of reading variations compared to standardized values can mean a Neuropsiquiatric diseases.

Because there are different types of neuropsychiatric diseases, various analysis and testing techniques have been developed, which seek to stimulate and analyze the response of users to these stimuli. Many of these tests are based on visual or auditory stimulation techniques, in addition to other techniques that measure the speed and range of response to different problems. These techniques tests are used in the areas of psychology and psychiatry to help diagnose the range and type of neuropsychiatric diseases that may be present in the person.

In this project the development of a sampling system of encephalographic signals stimulated by visual evoked potentials is disclosed. Through the design and construction of an analog sensor, the reading, amplification and filtering of encephalographic signals captured by dry electrodes is proposed. These signals are processed and taken to digital values to be sampled and analyzed by statistical techniques that allow the signal variations to be recognized and standardized against stimuli of visual evoked potentials presented at different frequencies. This system is proposed as a support system for the interpretation of data that may indicate neurodegenerative diseases with which psychologists and psychiatrists can work and diagnose patients.

2. PROBLEM STATEMENT

Neurodegenerative diseases are very common in the world population, in these, there are different symptoms depending on the type of existing neuronal condition. In many cases, the root causes of the diseases are unknown, which leads to an increase in this type of illnesses when a correct diagnosis is not made, affecting the quality of life of the people who suffer from it and those around them by, in many cases, the necessity for support staff to perform daily tasks. On different occasions, severe pain can occur due to the disorders, the medications to treat them are very expensive, resulting in not all people suffering from these diseases having sufficient acquisition capacity for them. Around the world there are more than 100 such diseases, 30 million people in the world suffer from Alzheimer's disease, others such as Parkinson's, senile dementia and amyotrophic lateral sclerosis are common neurodegenerative diseases. [66].

Furthermore the study of brain functioning has many procedures used to obtain the result of clinical evaluations, the techniques for this analysis can be: image-based techniques such as: positron emission tomography, magnetic resonance imaging, techniques as in study of bioelectrical signals such as magnetoencephalography and EEG, in this technique are found evoked potentials (EP) [35], The EP are tools to know and study the information processing of the nervous system, the information resulting from time variations in scale of milliseconds, This non-invasive technique shows the doctor an overview of the functioning of the brain with a specific sensory pathway depending on the stimulus. [66], the classification of PE depends on the type of stimulus such as: VEP, AEP and SSEP.

In Colombia according to the magazine the universal based on figures from the Danish public an article on May 23, 2019, this article makes reference that for every 100 people under 15, there are 40 people over 60, Colombia is getting older fast projections dictated, hearing and vision are two of the senses that are most quickly affected by age having consequences negative in people's quality of life, this document focuses on vision and non-invasive method to determine changes in the nervous system of the person through visual stimuli.[75]

Visual evoked potentials (VEP) are evoked potentials (EP) caused by visual stimuli that allow analyzing the behavior of brain electrical activity. The responses to visual stimuli are determined by a different sensory organ that is used in the diagnosis of certain neurodegenerative diseases, this allows identifying lesions neurological in almost any area of the nervous system. VEP is especially useful in patients who cannot express whether they are able to notice external stimuli for different reasons. [68].

Visual stimuli in VEP´s are used to focus the analysis at present changes of primary visual cortex in the occipital lobe. Relevant information providing by Visual stimuli is used to determine possible abnormalities [50]. Diagnostic methods of VEPs more used are the Flash method (currently this method is no longer widely used) and the CHECKER-BOARD test, this consists of displaying a chessboard on a screen, which is presented at different frequencies, widths of boxes and intensity of colors. [40]

VEP´s instrumentation uses different electrodes or sensors to be managed and placed in strategic parts of the patient's body to receipt and transmit impulses or bioelectric signals generated. Patients that are put in the test must-see in a screen the center point showing a chessboard. The screen shows black and white squares alternately change position to generated visual stimuli. This test requires the collaboration of the patient, to people with difficulty of concentration or repetition of tasks (case of children under 7 years), is used variations of light intensity produced by a flash. Signal processing and algorithms permit to determine the electrical brain activity to give a possible diagnosis. [51]

The human body presents different types of signals that can interfere in signal capture. VEP´s techniques use different strategies to reduce noise, the locate of electrodes or sensors is usually sought at a strategic point that allows the better captured of signals, filters that compare an original noise sample with the newly acquired signal are also used to eliminate the signals that cause interference and leaving only signals that interest in diagnosis. [56]

VEP's more important advantage is to be a non-invasive neurodegenerative pathological diagnostic test, the test is painless and rarely generates side effects in people, it is a quick and simple method to perform. (Mart.) [51]

VEP's common signal capture problems are the presence of noise generated by the human body and external signals. The human body generates a wide variety of electrical signals that move throughout the nervous system. All external signals to those involved in diagnoses of signal capture must be eliminated using analog or digital filters that are better adapted to the types of signals. [55]

The operation of the equipment must be realized by a trained operator who has the facility to calibrate and tune the signal capture equipment to eliminate all external and internal noise from the desired signals. The calibration and location of the electrodes is key to an optimal analysis, but this process is long and complex, and only one error can affect diagnostic signals. [67]

These types of equipment have a high price despite their use (Dantec ™ Keypoint® Focus $ 75,000 USD). The need to import them for lack of national manufacturing results in increased costs and time.

From the above, a question is generated that permit frame and direct the researcher.

How to manufacture a prototype of visual evoked potential equipment in our country focus on noise reduction to easiness his used and to reduce costs and time to market by offering the same types of analysis and the same guarantees of high-cost equipment?

3. OBJETIVES

3.1 GENERAL OBJETIVE

Develop a prototype to noise reduction sensor for evoked visual potentials at low cost.

3.2 SPECÍFIC OBJETIVES

- Develop a prototype to VEP's noise reduction sensor from analog and / or digital filters
- Implement at CHECKERBOARD test in JAVA apply an imageJ plugin.
- Analyze wave's brain signals acquired from sensor prototype by statistical analysis.
- Evaluate measured brain signals with brain signals from the literature.

4. CONCEPTUAL FRAMEWORK

The conceptual framework will be explained based on the conceptual map of the figure 1.

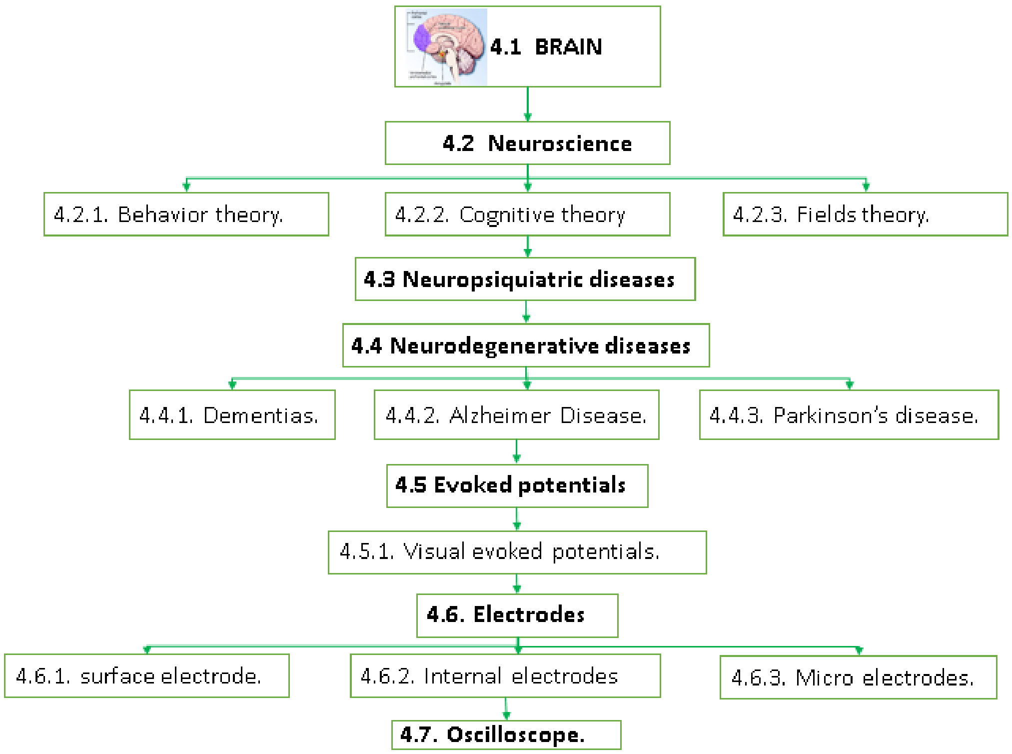


Figure 1. Topics to be discussed conceptual framework

4.1 BRAIN

The brain is biologically the most important organ of the human being, Over the years, scientists have investigated the different functions developed by this body [13], investigators discovered that this the commission of all the vital functions of the human being, executive functions as: self-control, reasoning, Abstract thinking and be the organ where the conscience and the mind of the people reside [61].

In recent years has been rambling about the evolution of this body carrying studies and theories as: number of neurons, transmitter connections, structure, and the size depending on the species, the size of the brain is closely related to the body size of people, It is also stated that the brain has about 80 billion neurons [65] [77], another one of the main theories of the brain is the one proposed by MacLean developed in 1952, it was originally named as the theory of the evolution of the atomic structures of the brain in time, this theory divides the brain into three brain regions, see figure 2, the regions are: reptilian or primitive brain, it is charge of the instincts, feeding, survival, defense, reproduction processes among others, another region is the limbic brain whose function is to control the nervous system, in this are the emotions, the memory, the learning. and finally, the neocortex brain in charge of advanced thinking, logic, analysis [51].

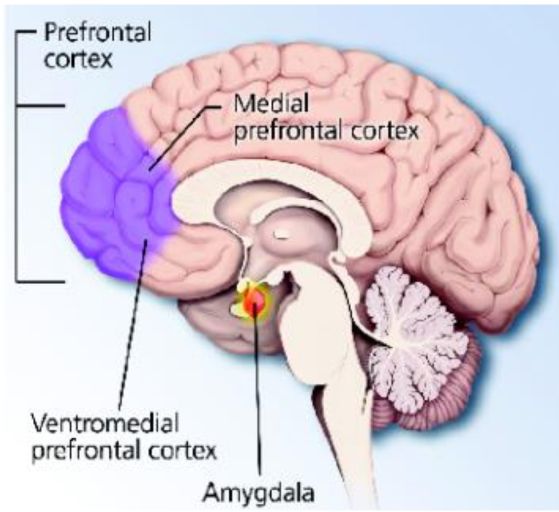


Figure 2. Brain regions. [51]

The curiosity to investigate about the brain has generated the creation of new sciences that seek to find and define the behavior of the same thanks to different technologies such as scanners that help identify how this organ works and how it works [44] these disciplines are called brain sciences, neuroscience is one of the most named sciences and this is responsible for studying the nervous system [51].

4.2 NEUROSCIENCE

Neuroscience tries explain how behavior occurs the neurons found in the brain, trying to understand the behavior of people, that is, how they learn, how information is stored, how they are biological processes, how is it shared memory, and how it reacts to different stimuli, also it seeks to determine the structure and how the brain has evolved and find alternatives to prevent and cure neurobiological diseases [51], research is still underway to determine the behavior of the brain [41], nevertheless, it is very complex because each person behaves in a different way in such a way that complicates the results of these investigations, the most important technologies that gave way to the development of neuroscience are the neuroimaging techniques, neuroimaging is divided into two groups, the first group is called structural, which consists of taking computerized images, the best known are computed tomography (CT), magnetic resonance imaging (MRI) and the second group called functional, which consists in making direct measurements of neural activity, among which electroencephalography (EEG) and encephalographic magneto (MEG) are known [29]

The main theories of neuroscience are those focused on learning which consist of postulates that describe the way people learn new ideas, new concepts, this theory is subdivided into two fundamental groups [31]:

4.2.1. Behavior theory. The main contributors to the development of this theory is Pavlov, Watson, Thorndike and Skinner, this theory is based on analyzing the behavior of people when learning new knowledge based on stimuli received from the environment [78], Watson was the first psychologist to conduct behavioral experiments on animals and Pavlov and Thorndike did studies on people to determine how was the reaction to these stimuli, in this theory the mind is seen as a black box in which responses are obtained from a stimulus ignoring the possibility that some process may occur in the mind, this behavioral theory is one of the main theories of human learning, this theory presents learning as if it were a mechanical, inhuman and reductionist process generating uncertainty. [26]

4.2.2. Cognitive theory. This theory is based on studying the way in which knowledge is generated, it determines that one of the main factors to create knowledge is experience. nevertheless, this theory depends mainly on the subject who is able to build knowledge based on experiences of the outside world, some authors like said that cognitive theory "is a process of maturation in which from the first stimuli we are maturing the nervous system and we are organizing our map" [7] Learning is acquired with psychic and physical maturation. " Another author is Ausunbel, who defines it as "meaningful learning is going to happen when something really interests us, draws our attention or leaves its mark on us." and Vygotsky defines it as "we learn individually, by the interaction of the environment and the environment in which we live, always in a group, by imitation, social internalization, and interaction with the group" [82].

Another of the main theories that have been developed from neuroscience

4.2.3. Fields theory. Proposed by the American psychologist Kurt Lewin in the year 1935, Kurt determined that the behavior of people is determined from a balance between the subject and the environment or external environment in order to eliminate possible tensions by generating new knowledge [23].

Among the different fields of action of neuroscience are those who seek answers to questions such as, ¿How the brain is structured? ¿ How the memory of the people resides? ¿What determines the behavior of each person? Another one of the main fields is the one that studies the diseases, neurobiological pathologies and mental illnesses, for the study that is tried to develop only the neuropsychiatric alterations will be analyzed [40].

4.3 NEUROPSIQUIATRIC DISEASES

Neuropsychiatric diseases are alterations that are characterized by having different behaviors from the norms established by the community, the main symptoms are: disturbance of thought, mood changes, different behaviors in short periods of time these manifestations can be presented physically, emotional, cognitive, perceptual and / or behavioral [31].

Countries where the highest rate of neuropsychiatric diseases are found: Iceland, Finland, France, Israel, Chile, Malta, Luxembourg, Mexico, Norway, Switzerland or the United States, and it is estimated that by 2020 the burden of these alterations will be 24%, Table 1 shows the percentage of some percentages of countries that suffer from this disease, in figure 3 the average for Colombia is observed 21.7%. [15]

Country	Percentage neuropsychiatric diseases (%)
Colombia	21.7
Chile	30.5
U. S	29.6
France	29.7
Switzerland	31.2
Canada	32.4

Table 1. Percentage of neuropsychiatric diseases in the world.

Figure three shows the population levels worldwide with the highest rates of prevalence of neuro-psychiatric diseases.

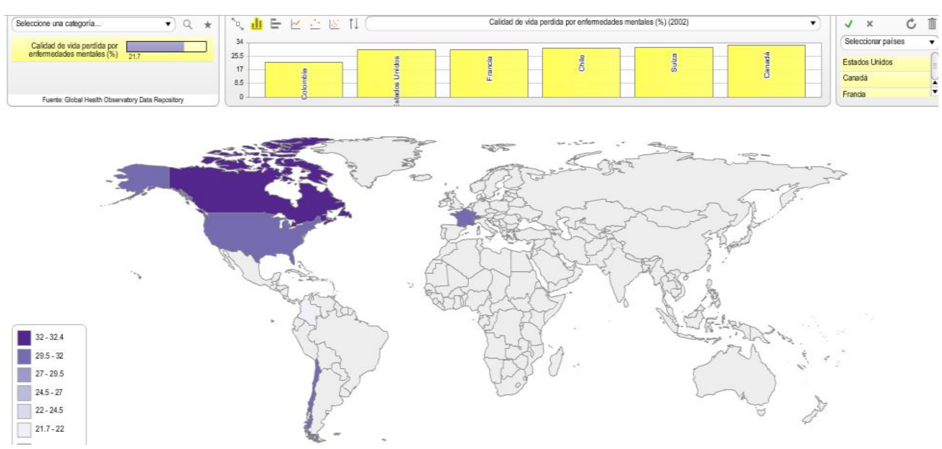


Figure 3. Percentage of neuropsychiatric diseases for Colombia. [15]

Neuropsychiatric disorders have a high impact on the quality of life of people who suffer from it, at present there is a high rate of people suffering from this type of diseases, these disorders can occur both in men and women and in different stages and ages of people [35].

4.4 NEURODEGENERATIVE DISEASES

Neurodegenerative diseases affect the world population, this disease generates low quality of life due to the circumstances in which a person with this disease lives, such as: strong and intense pain, problems remembering things and other factors such as economic, this is of great importance since the treatments of these neurodegenerative diseases are high and in some occasions the EPS do not respond. [53].

4.4.1. Dementias. Dementia is a clinical syndrome characterized by a deficit acquired in more than one cognitive domain, which represents a loss with respect to at the previous level and that significantly reduces functional autonomy. Dementia often involves behavioral and psychological symptoms that produce important limitations in activity and restrictions on participation.

Degenerative dementias are diseases characterized by neuronal and synaptic loss and the cerebral deposition of intra and / or extracellular insoluble protein aggregates.

Most degenerative dementias are diseases that appear in more advanced ages, from the age of 65, and are sporadic, although in almost all of them there are hereditary forms and early start forms. They start insidiously, to follow a course progressive and irreversible. [83]

Mild dementia: the patient has difficulty in developing their work or profession but does not need help for daily household activities. The scan finds a loss of recall memory for recent events and changes in the denomination begin to appear [83]

The patient has difficulty developing some domestic activities, cognitive impairment is evident, the evocation memory loss is intense and there are slight alterations in some of these areas: language, visuospatial function, praxia, gnosia, abstract thinking and executive function [83]

the patient needs help for most or all the daily activities. Cognitive alteration is manifest in all fields. [83]

4.4.2. Alzheimer Disease. Alzheimer's disease is the most common form of dementia among the elderly. Dementia is a brain disorder that severely affects a person's ability to carry out their daily activities.

Alzheimer's begins slowly. It first affects the parts of the brain that control thinking, memory and language. People with evil may have difficulty remembering things that happened recently or the names of people they know. A related problem, mild cognitive impairment, causes more memory problems than normal problems in people of the same age. Many, but not all people with mild cognitive impairment, will develop Alzheimer's. [11]

Over time, Alzheimer's symptoms get worse. People may not recognize their relatives. They may have difficulty speaking, reading or writing. They can forget how to brush their teeth or comb their hair. Later, they can become anxious or aggressive or wander away from home. Finally, they need total care. This can be very stressful for family members who must take care of their care.

Alzheimer's usually begins after age 60. The risk increases as the person ages. The risk is greater if there are people in the family who had the disease.

No treatment can stop the disease. However, some drugs can help prevent symptoms from getting worse for a limited time. [11]

Alzheimer's Symptoms. Signs that indicate Alzheimer's disease may include:

- Personality changes
- Impaired movement or walking ability
- Difficulty communicating
- Low energy level
- Memory loss
- Mood changes
- Attention and orientation issues
- Inability to solve simple arithmetic operations [62]

4.4.3. Parkinson's disease. Parkinson's disease is a progressive disease of the nervous system that affects movement. symptoms begin gradually. sometimes, it begins with a barely noticeable tremor in one hand. tremors are common, although the disease also usually causes stiffness or decreased movement.

In the initial stages of Parkinson's disease, the face may have a slight or no expression. Your arms may not swing when you walk. Speech can become soft or incomprehensible. The symptoms of Parkinson's disease get worse as it progresses over time.

Although Parkinson's disease has no cure, the medications could significantly improve symptoms. Occasionally, the doctor may suggest surgery to regulate certain areas of the brain and improve symptoms. [19]

4.4.3.1. Parkinson's symptoms. The signs and symptoms of Parkinson's disease may be different for each person. The first signs may be mild and go unnoticed. Often, the symptoms begin on one side of the body and usually continue to get worse on that side, even after the symptoms begin to affect both sides.

- **Tremors:** A tremor, or shaking, usually begins in a limb, often in the hand or fingers. You can rub your thumb and forefinger back and forth, which is known as a pill bearing tremor. Your hand may shake when it is at rest.
- **Slow movement (bradykinesia):** Over time, Parkinson's disease can slow your movement, making simple tasks difficult and take longer. Your steps may be shorter when you walk. It can be difficult to get up from the chair. You may drag your feet while trying to walk.
- **Muscle stiffness:** Muscle stiffness can occur anywhere in the body. Rigid muscles can be painful and limit your possibility of movement.
- Impaired posture and balance: The posture may become hunched over or you may have balance problems as a result of Parkinson's disease.
- **Loss of automatic movements:** You may have a reduced ability to perform unconscious movements, such as blinking, smiling or swinging your arms when you walk.
- **Changes in speech:** You can speak softly, quickly, insult or doubt before speaking. Your speech may be more monotonous due to the lack of the usual inflections.
- **Changes in writing:** It may be more difficult for you to write and your letter may seem small. [19]

4.5 EVOKED POTENTIALS

the evoked potentials (EP) are diagnostic techniques that help explore, the nerve pathways that lead the different organs to the brain, the way to perform the EP tests depends on the type of stimulus performed, evoked potentials use electrodes for registration which are placed in the scalp, the location of the electrodes depends mainly on the type of exam and analysis required.

Exist three types of evoked potentials:

- Sensory: neurophysiological response to sensory stimulation.
- Engines: nervous system response of various muscles.
- Reflexes: motor response to sensory stimulation.

In relating to the stimulated sensory organ:

- Auditory Evoked Potentials (AEP).
- Somatosensory evoked potentials (SEP)
- Motor evoked potentials (MEP)
- Visual evoked potentials (VEP)

This document focuses on visual evoked potentials. [39]

4.5.1. Visual evoked potentials. The visual pathway is a set that represents the most complex sensory system quantitative and qualitative, the retina allows to record the variations of potential that cell layers generate, and this can see their structure. the VEP to help identify the general shape of the brain, the VEP test helps to register the cortical part of the brain.

VEP identify five important synapses such as: three are from the retina and two from the brain.

The most important factors of VEP are: the quality of light the area of the retina that is stimulated, type of figure, chromaticity, contrast, position, frequency of the stimulus. [48]

Visual evoked potentials are stimulated by two ways such as: intermittent light and the reversible pattern, through a television screen that shows a chess board. In general, the response to the stimulus with the reversible pattern is more sensitive to minimal changes in vision, than intermittent light, which is most useful in visual behavior.

Different articles describe that the visual responses evoked are very difficult to acquire because the scalp interferes with the measurement, and different factors such as: hair, network frequency, humidity, signal of
heart.

other factor important for measure depend on electrode type used because these captures biological activity, such as brain waves or muscle potentials for this reason is necessary use different electrodes with aim that acquired best measure without interference. [72].

4.5.1.1. checkerboard testing VEP. in potentials evoked visual exist a test with the name checkerboard that help to identify the different brain waves, these waves serve for diagnostic the neurodegenerative disease. in this case the doctor can analyze the result and help to patient for diagnostic.

The idea of checkerboard is show un board that change the color between black and white in a determine time. The objective is to can determine changes in the brain waves. In this graphic represent the board [72].

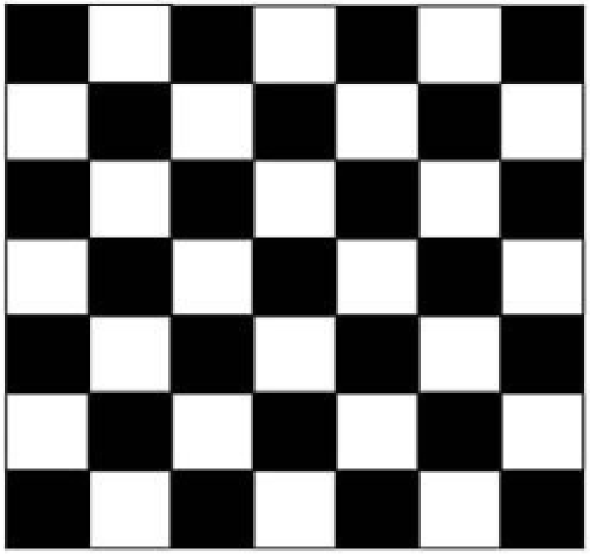


Figure 4. Checkerboard Interface test. [72]

4.6. ELECTRODES

The electrodes in medicine are devices or sensors for measure signals how: health signal, brain signal, electric activity of body in others.

In the actuality exists different types depend on the signal or application [51].

4.6.1. Surface electrode. The surface electrodes are placed in contact with the patient's skin. The diameter of these electrodes is 0.3 cm to 0.5 cm.

The main problems are: the patient's skin has a problem or disease, there is an increase in impedance.

4.6.1.1. Suction electrode. The suction electrodes are electroencephalography sensors. These electrodes do not need tapes or adhesives. [25]

Figure 5. Suction electrode. [3]

4.6.1.2. Floating electrodes. Floating electrodes have an electrolytic paste, this paste is found in the electrode cavity. Direct contact of the sensor with the skin is not necessary on these electrodes. [25]

Figure 6. Floating electrodes. [3]

4.6.1.3. Flexible electrodes. Flexible electrodes are adaptable to the body surface. These electrodes have better contact with skin surfaces. The flexible electrodes are made with adhesive material and on top it has silver wires in the form of a mesh. [25]

Figure 7. Flexible electrodes. [3]

4.6.1.4. Dry electrodes. Dry electrodes are used in encephalography, these electrodes do not use conductive paste, therefore they capture a lot of interference. [25]

Figure 8. Dry electrodes. [3]

4.6.1.5. Internal electrodes. These electrodes are inserted into the human body; They are invasive elements. these electrodes are used for medical use only. [25]

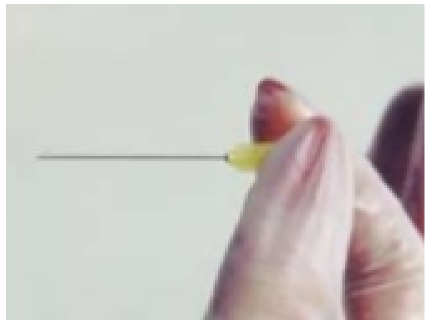


Figure 9. Internal electrodes. [3]

4.6.1.6. micro electrodes. Micro electrodes are used to measure the potential that is generated between the outer and inner parts of the cell membrane. the unit of these electros is between the micro. [25]

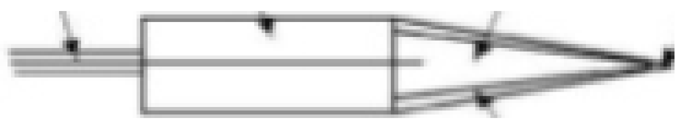


Figure 10. Micro electrodes. [3]

4.7. OSCILLOSCOPE.

in electronics the oscilloscope is a measuring instrument used to calculate different measurements. In this device the amplitude is represented on the vertical axis and on the horizontal axis the time, oscilloscopes can be analog or digital, digital oscilloscopes are used more today.

Digital oscilloscopes are made up of an LCD screen. Digital oscilloscopes have the facility to transfer measurements to a computer. in these oscilloscopes the signal is digitized by an analog / digital converter. In the oscilloscope it is possible to measure time, amplitude, lags, frequencies, bandwidth, among others. [48]

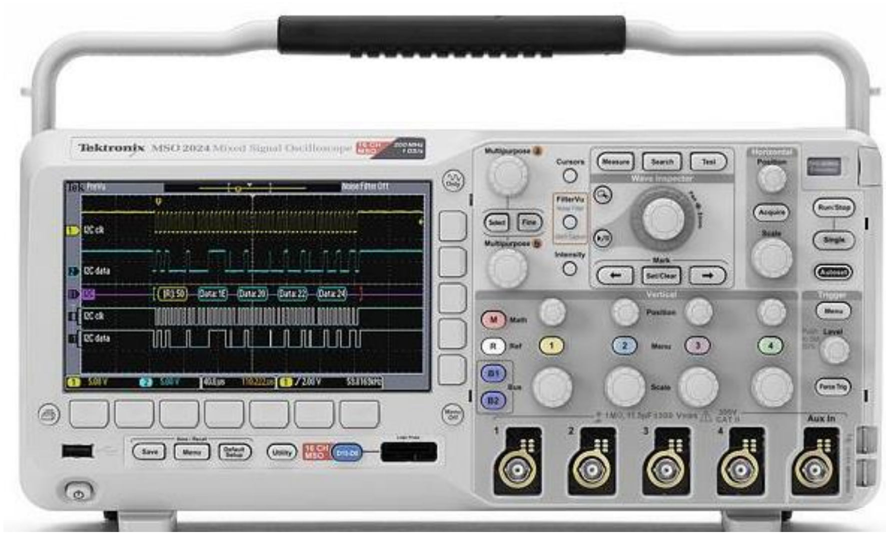


Figure 11. Oscilloscope. [48]

5. THEORETICAL FRAMEWORK

The research focused on the theory applied to the use of analog filters and digital filters for signal capture. This was implemented to read encephalographic signals classified according to the type of signal and were used to study visual evoked potentials.

5.1 ANALOG FILTERS:

An analog filter is called to manage and be focus on the handling of signals that are not discretized and unused of algorithms. The filter is made up directly of elements such as resistors, coils, capacitors, and operational amplifiers, which are ultimately the ones that perform the filtering.

The operation of an analog filter is based on the "Jean-Baptiste Joseph Fourier" formula, which is based on the distribution of heat in a solid body, from which a series of formulas known as "Fourier Series" follows. The equations are described as the calculation of a signal in time defined as the sum of a DC level, and several sine, and cosine signals, of different magnitude and phase, thanks to this a signal in time can also be represented in frequency [84].

The Fourier series associated with F (t) which is a function of real variable integral in the interval [to –T/2, to +T/2], is represented as:

$$F(t) \cong \frac{a0}{2} + \sum_{n=1}^{\infty}\left[anCos\left(\frac{2n\pi}{T}t\right) + bnSin\left(\frac{2n\pi}{T}t\right)\right]$$

Where ao, an, and bn are the Fourier coefficients that take the values:

$$ao = \frac{2}{T}\int_{-T/2}^{T/2} F(t)dt$$

$$an = \frac{2}{T}\int_{-T/2}^{T/2} F(t)Cos\left(\frac{2n\pi}{T}t\right)dt$$

$$bn = \frac{2}{T}\int_{-T/2}^{T/2} F(t)Sin\left(\frac{2n\pi}{T}t\right)dt$$

Applying the Fourier series in the use of filters, the deformation of an input signal is obtained. A filter used for sources where the capacitor is placed after the diode bridge, affects the input sine voltage signal, causing the DC level to be at the output, doing so damages the power factor. Applying filters on audio signals is different since what the looking for with filters is to always eliminate noise, cleaning the input signal, in addition to sometimes also want to amplify special frequencies.

There are four basic types of filters, the high pass filter, the low pass filter, the band pass filter, and the band reject filter. Each with its specific function [84].

- The high-pass filter only allows high frequencies to pass from the cutoff frequency.
- The low-pass filter lets low frequencies pass before the cut-off frequency.
- The band-pass filter only allows some frequencies that are found between the cutoff frequencies, eliminates all the others.
- The band-rejects filter lets all the frequencies pass and eliminates those that are between the cutoff frequencies.

In an ideal filter, the unnecessary frequencies would be totally eliminated before or after the cutoff frequency according to the filter used, but in reality this is not the case, these are attenuated, depending on the order of the filter, and its configuration.

5.1.1 High-pass filter. The main characteristic of high-pass filters is to attenuate the signal at low-frequency values. Some high-pass filters also lead to phase overtaking and signal shunt. A high-pass filter allows all frequencies above its cutoff frequency to pass through without attenuation. Frequencies below the cut-off point will be attenuated. As the frequency below the cut-off point decreases, this attenuation, defined in dB per octave, increases. Standard high-pass filters follow increments of 6 dB per octave, so filters of 6 DB, 12 DB, 18 DB, and 24 DB per octave are common [84].

The transfer function of a first order high pass filter corresponds to:

$$H(s) = \frac{S/Wc}{1 + S/Wc}$$

where Wc refers to the cutoff frequency given by:

$$Fc = \frac{1}{2\pi RC}$$

where R is the value of the resistance of the resistor and C of the capacitor of the capacitor.

The most common applications for high-pass filters are to remove or at least reduce unwanted information in the signal spectrum below 40 hertz to 70 hertz. In audio applications are removed the sub-audio signal like stage rumble (5 hertz to 30 hertz) and wind or breath noise (40 hertz to 70 hertz).

5.1.2 Low-pass filter. The Low-pass filters are those that introduce very little attenuation at frequencies that are less than a cutoff frequency. Frequencies that are higher than the cutoff are strongly attenuated [84].

The transfer function of a first order high pass filter corresponds to:

$$H(s) = k\frac{1}{1+\frac{S}{Wc}} = k\frac{1}{1+sRC} = \frac{Vout(s)}{Vin(s)}$$

Where k is the filter gain.

where R is the value of the resistance of the resistor and C of the capacitor of the capacitor.

The low pass filter basic is a series RC circuit in which the output is the voltage drop across the resistor. The operation of these circuits based in the capacitor where this will present a great opposition to the passage of currents due to low frequencies and as it forms a voltage divider with the resistance, almost all the input voltage will appear on it. For high frequencies, the capacitor will present little opposition to the passage of the current and the resistance will remain almost the total of the input voltage, with very little voltage appearing at the ends of the capacitor.

5.1.3 Band-pass filter. The band-pass filter allows a range of frequencies of a signal to pass through and attenuates the passage of the others: there handling two cutoff frequencies ($WC1$ & $WC2$), one lower and one higher. The filter only greatly attenuates signals whose frequency is less than the lower cutoff frequency or those of frequency higher than the upper cutoff frequency, these only allow the passage of a range or frequency band without attenuation [84].

The transfer function of the second order band pass filter is given by:

$$H(s) = \frac{Vout(s)}{Vin(s)} = k\frac{s\frac{Wo}{Q}}{S^2 + S\frac{Wq}{Q} + Wo^2} = k\frac{s(Wc2 - Wc1)}{S^2 + S(Wc2 - Wc1) + Wc2Wc1}$$

Where $WC2$ is greater than $WC2$.
Where k is the filter gain.
Where Q is the quality factor (selectivity) and is given by:

$$Q = \frac{\sqrt{WC1\,WC2}}{WC2 - WC1}$$

In a band-pass filter the center frequency is the geometric mean of the cutoff frequencies. The cutoff frequencies correspond to the gain k over the root of two. A high quality factor Q indicates that the filter becomes more selective, but does not imply that the filter is more like an ideal filter. The only way to take the form of an ideal band-pass filter is to work with higher order filters.

5.1.4 Band-Rejects filter. The Band-Rejects filter or Notch filter eliminates at its output all signals that have a frequency between a lower cutoff frequency and a higher cutoff frequency. Therefore, these filters eliminate an entire band of frequencies from those introduced as input [84].

The common form of implementation consists of two filters, one low pass whose cutoff frequency is the lowest of the filter eliminates band and another high pass whose cutoff frequency is the highest of the filter eliminates band. Since both are linear and invariant systems, the frequency response of a band-cut filter can be obtained as the sum of the low-pass response and the high-pass response.

The transfer function of the band rejects filter is given by:

$$H(s) = \frac{Vout(s)}{Vin(s)} = k\frac{S^2 + \frac{R1 + Rx}{R1^2 RxC1C2}}{S^2 + S\left(\frac{2}{R1C1} + \frac{1}{R1C2} - \frac{1}{RxC1}\right) + \frac{R1 + Rx}{R1^2 RxC1C2}}$$

Where:

$$R1 = \frac{1}{2\pi FoC2}\sqrt{\frac{m+1}{m}}$$

$$Rx = \frac{1}{2\pi FoC2}\sqrt{\frac{m+1}{m^3}}$$

$$C1 = mC2$$

$$m = \frac{-1 + \sqrt{1 + 16Q^2}}{2}$$

The values of $C2$ are choose by the designer. The magnitude of this filter in Fo is zero, and when the frequency is zero or infinity it is equal to gain k. Likewise, the magnitude at the cutoff frequencies of gain k over the root of two (0.7071 k). The design equations are the same for both the filter rejects non-inverter band and the filter rejects inverter band.

5.2 DIGITAL FILTERS

A digital filter is a filter that operates on digital signals. It is a mathematical operation that takes a sequence of numbers (the input signal) and modifies it producing another sequence of numbers (the output signal) in order to highlight or attenuate certain characteristics. Depending on the variations of the input signals in time and amplitude, a mathematical processing is carried out on signal. Through the use of the Fast Fourier Transform the variations are make and obtained in the output the result of the mathematical processing or the output signal. The easiest way to implement a filter is to convolve the input signal with the impulse response of the filter [85].

There are two types of digital filters implemented in the time domain:

- FIR Filters (Finite Impulse Response)
- IIR Filters (Infinite Impulse Response)

5.2.1 FIR filter. FIR filter is a type of digital filter whose response to an Impulse signal as input will have a finite number of non-zero terms. these are implemented with convolution and perform weighted multiplication sums between the signal and the feedback [85].

The filter expressed as a function of z and as a fraction equals:

$$H(z) = \sum_{k=0}^{M} Hk\ Z^{-k} = H0 + H1Z^{-1} + \cdots + HnZ^{-(N-1)}$$

Where $N - 1$ is the filter order and H is the response in impulses

FIR filters have the great advantage that can be designed to be a linear phase, which means that these have certain properties in the symmetry of the coefficients as well as being always stable, the disadvantage is the need to have a higher order than the IIR filters to fulfill the same characteristics, this meaning a higher computational expense.

5.2.2 IIR filter. IIR filters are a type of digital filters in which if the input is an impulse signal, the output will have an infinite number of non-zero terms, which is understood as a signal that never returns to rest. This type of filter presents an impulse response that decays infinitely in amplitude [85].

A filter expressed as a function of z and as a fraction equals:

$$H(z) = \frac{\sum_{k=0}^{N} Bk\ Z^{-k}}{\sum_{k=0}^{M} Ak\ Z^{-k}}$$

where Ak and Bk are the filter definition coefficients and therefore with which the design is carried out.

This type of filters has poles and zeros that determine the stability and causality of the system. When all the zeros and poles are inside the unit circumference, meaning that it is a minimal phase and the system is stable and causal. If all zeros are on the outside it is maximum phase. If any pole is outside the unit circumference, the system is unstable.

5.3 DIGITAL SAMPLING

Sampling is defined as the number of times the signal value is measured in a period of time, the number of times a signal must be measured in order not to lose information, it must be at least double the maximum frequency that reaches signal. Digital sampling is one of the parts of the signal digitization process. It consists of taking samples of an analog signal at a constant frequency or sampling rate, to quantify them later.

To carry out digital sampling it is necessary to carry out an analog-digital conversion (CAD), this consists of transcribing analog signals into digital signals, in order to facilitate their processing (encoding, compression, etc.) and make the signal resulting (digital) more immune to noise and other interferences to which analog signals are more sensitive [86].

The digital signal is translated as the sum of impulses where:

One impulse $P(t) = 0$ to $|t| \geq \frac{Ts}{2}$ set the wave as:

$$Xpi(t) = \sum_{m} x(mTs)p(t - mTs)$$

Where $x(mTs)$ is the scale factor (Amplitude)

Finally, the sampling wave establishes that it is made up of impulse trains of non-zero duration. Practical rebuild filters are not ideal. The signals to which the sampling theorem is applied (twice the sampling frequency) are not strictly band-limited, this limited the time signals.

6. STATE OF THE ART

For the documentation of this project, searches were made for scientific articles focused on neuroscience, giving priority to those that indicate procedures for reading and analyzing neural signals. The search margin focused on the last ten years (2010-2020), in order to give truthfulness and verifiability to the work done.

The development of neuroscience has been critical in the evolution of humanity; The study of the behavior of the brain has been one of the most popular topics that research carried out in the last decades has had, for which reason various researches and articles have been developed in different areas of interest [82]. The application of neuroscience in the 21st century generates different challenges regarding training methods for the different entities that apply and promote it. As a constantly evolving science, neuroscience is constantly updating conceptual approaches, scientific tools, and clinical applications [5].

Within the different branches of neuroscience, those that focus on clinical studies have been some of the ones that have presented the most development, together with other branches that strengthen detection processes and psych-clinical interventions. The processes that focus on cognitive behavioral therapy studies present different application points that allow interdisciplinary management of the different aspects that may arise in therapies and disciplinary processes [De Raedt20]. Neuroscience has shown that it can be applied in the detection, analysis and diagnosis of neuronal disorders, in addition to serving as support for psychiatric and psychological treatments as a support and complement tool [25].

In clinical aspects, studies of mental disorders are always handing with neuroscience analysis, identifying and analyzing the areas that are affected due to the generation of mental disorders. Throughout history, different reasons have been speculated for the generation of these disorders, seeking to identify the causes and possible treatments that allow reducing or eliminating disorders that affect different people [24].

Due to the large number of studies that have focused on the analysis of neuronal diseases, many of these have been shown to be due to genetic abnormalities, which affect the brain's work areas in various ways. In antiquity, diagnoses were presented in a subjective way, which generated failures in the detection of neuronal failure; Thanks to the implementation of technological equipment, the study and diagnosis of the type of disease present has been facilitated [23].

In conjunction with psychoanalysis, neuroscience gives a new understanding of concepts such as the embodiment of the mind, consciousness and attachment; It also allows improving treatments and giving rise to new experimental neuroscientific paradigms that involve changes in research and objectives, generating new objects of study and analysis [56].

Neuronal diseases as a study area of neuroscience have always been a central point of development [63], seeking to identify and generate behavioral models that indicate and allow the different types of disorders to be classified [8]. The different studies that have been carried out in different countries over the years have made it possible to identify and classify the different types of disorders that exist, but likewise, a growth in the types of disorders and the number of people affected has been identified [73].

Genetic studies have made possible to classify in a more adequate way the neuropsychiatric disorders that are currently present, and that on many occasions have been misdiagnosed due to deficiencies in existing theory. New methods of genetic diagnosis together with the application of neuroscience have given rise to new, more accurate and consistent classification and diagnostic methods [57]. As one of the most common disorders, Autism Spectrum Disorder is one of those that affects a larger population. This has been shown to be a neurologically based disorder that can be treated by behavioral interventions in which neuroscience is of great importance as a method of measurement and diagnosis, generating information that allows understanding the degree of involvement and the type of procedure to follow [68].

Another disorder that greatly affects people is Alzheimer's; Through neuroscience application processes, research focused on treatment for this type of disorder has been carried out, seeking to identify the reasons why it is generated and possible solutions or treatment that can reduce or eliminate this disorder [46]. An early diagnosis of Alzheimer's would allow reducing the negative effects that this neurodegenerative disease produces, but due to the different diagnostic methods, it is not recognized until it is at an advanced stage. In response to this problem, early diagnosis processes have emerged as a possible solution, giving early knowledge of the presence of the disorder and possible treatment [65].

The use of neuroscience in the obsessive-compulsive disorder has allowed studying the areas that are affected when faced with the stimuli that cause the obsession, in the same way identifying the processes that generate reactions on stimuli and the person's actions. involved. These studies have opened a new field in the treatment of addictions and in trauma detection [70]. Some types of addictions have been treated as neuronal disorders. Through neuroscience seek to identify the levels of addiction in which people are, and if these have been generated by health deficiencies or mental disorders [37].

Brain mapping processes have facilitated the characterization and classification of the areas affected by neural disorders, making it easier to understand how these affect various areas and to generate a classification of the type of disorder and the type of involvement it can generate [7]. Through different techniques such as neuroimaging processes, brain mapping has been possible, identifying through stimulation processes and magnetic resonance samples the different areas that are activated according to the type of stimulus, generating correlations between neurological processes and psychological processes [21]. In conjunction with theoretical neuroscience, the application of neuroimaging processes allows a more complex understanding of network connectivity with the dynamics of neural activity, giving a better understanding of the structures and measurements that make up neural models [18].

Different neuroimaging techniques are under development promoting imaging techniques to analyze the brain in different environments, focusing on the analysis of social environments in which the brain has different characteristics and greater activity [32]. The evolution in brain mapping processes has generated new processes for the study and identification of cellular and subcellular areas, although these are usually complex, generate new study opportunities and further open the field of neuroscience research [47]. As a more complex type of brain mapping, multiscale neuroscience has emerged in order to identify the different scales that make up the different levels of organization of the nervous system among the structures, functions and behaviors of the brain [78].

Neuroscience has also undergone extensive development in the processes of diagnosing cerebrovascular injuries, allowing the types of injuries to be identified and the possible effects they may have in the short, medium and long term [36]. In the analysis of causes, various models of interconnections have been proposed to determine how motility is affected and apathy can be generated in compliance with actions aimed at body movements, identifying areas affected by cerebrovascular injuries [71]. Although cerebrovascular injuries are a big problem that affects people who suffer from it, these serve as a great source of information to understand the functioning of the brain and the different systems related to it. Neuroscience has evolved thanks to the large amount of information that has been extracted from different injuries that have been possible to study and analyze [78].

In the detection of common disorders, neuroscience has been used as a method of analysis to identify the cause of migraine. Although it is a fairly common disorder, its causes are highly variable and the affected areas are different for each person [13]. Similarly, processes that involve neuroscience as a diagnostic system have been used in people with chronic musculoskeletal pain, seeking to re-conceptualize the understanding of pain in a person as less threatening [80].

As a pain detection process, neuroscience has been applied in different cases of analysis in diseases such as cancer, pediatric and sports pain, identifying affectations on the peripheral and central nervous system, causing generalized hypersensitivity of the somatosensory system [43]. The drug diagnosis process in neuroscience has emerged as a response to the application of neuroscience for the diagnosis of various physical and psychological illnesses, generating a new branch of medication and response analysis [74]. It has been identified that the great problems of the treatment of neurodegenerative disorders through drugs, are due to a poor development of tests and statistical control that the different laboratories develop before sending to the market [8].

Aside from poor drug control and production techniques, neurodegenerative diseases have been shown to stem from decades of pathological cognitive decline, making drug effectiveness highly questionable, if not nonexistent. A prompt perception of neuronal disorders would make the effectiveness of drug-based treatments possible, reducing or eliminating the presence of neurodegenerative conditions [81]. Like response, the different tools that have emerged to support clinical neuroscience in addition to clinical trial methodologies provide a better understanding of the type of disorder, allowing for a better type of medication for antipsychotic drugs [64].

As a treatment, neuroscience has been used as a research method in identifying the body's immune process. For a large number of neurodegenerative diseases, neuroinflammatory conditions have been identified. These symptoms are related to the central nervous system and are those that the peripheral immune system treats as a priority. By detecting the actions taken by the immune system, neuroscience is promoting new treatments that promise to be more efficient on disorders such as Alzheimer's disease (AD) and multiple sclerosis (MS) [42].

More specific processes have used neuroscience as a control system over intracerebral pressure, detecting when an increase in intracerebral pressure can show malfunctions in the functioning of the nervous system and cause impairments in motor control or other neuronal disorders [44]. In specific disorders such as schizophrenia, neuroscience has been proposed as a starting point for the generation of new treatments that allow the reduction of cognitive deterioration generated by this type of disorder. Research and the generation of new techniques have been promoted in order to create new knowledge and encourage the application of these treatments in the clinical environment [15].

The use of Transcranial Magnetic Stimulation as a treatment for Autism Spectrum Disorder has opened a new trend of treatments using neuroscience as a development point, allowing by means of stimuli to reduce the conditions that are generated by the disorder, giving a better response in contradiction to treatments that involve drugs or invasive processes [16].

Child neurology has also been key in the development of neuroscience. The pediatric processes that focus on the study of neuroscience applied to the learning and detection of neuronal diseases in children, has been one of the most developed in recent years, generating treatment and new application developments that have opened new opportunities. to the investigation [59].

Treatments focused on irritability, one of the conditions that most affects children, has been one of the most researched fields of study in childhood neurology. Neuroscience has identified the amygdala, the medial prefrontal cortex, the cingulate cortex, the insula, the striatum and the association cortex are the areas that are most affected by irritability, and that these should be intervened to treat this disorder [40]. The application of neuroscience in children's neurology has been explored with greater force in recent years, promoting the study of this branch, making it one of the most researched and which is requested to be based on all training processes that involving neuroscience [30].

Cognitive neuroscience as part of the various branches of neuroscience, focuses on the study of the perception and understanding of the environment and the being in which people operate, since the human being is aware of its existence until it perishes [10]. The social environment is key in cognitive neuroscience, the way in which people and social groups are perceived affects in various ways the understanding of the environment in which a person develops [28].

One of the most accepted applications of cognitive neuroscience has been in the study of the potential impact of a brain injury generated by post-traumatic stress, in many cases applied to retired military personnel. [79]. Likewise, the study of bipolar disorder has been addressed by cognitive neuroscience, identifying by wave recognition those that appear most frequently for variations in moods, allowing the systematization of variable behaviors [33].

Some disorders such as Eating Disorder have been studied by cognitive neuroscience, identifying the areas and processes that intervene in the brain in the face of food consumption, and the detection of affected areas when this process presents abnormally [69]. As experimental processes, the application of neuroscience in episode memory has generated various applications on the results that are perceived on different patients, generating different methods of application of stimuli to stimulate or create variations on this type of memory [45].

Cognitive neuroscience also promotes techniques for preventing neural diseases. Healthy lifestyle habits like exercise have shown a high induction in neurogenesis in the brain, with the potential to improve brain health and avoid the effects of neurodegenerative disease [62].

In the development of cognitive neuroscience, computational cognitive neuroscience (CCN) has been key in the analysis and compression of the different interconnected and related systems that generate neural processes, analyzing processes and identifying brain areas of interest, allowing verify or contradict with classical theory [26].

Cognitive computational neuroscience as a system of analysis of human behavior has been studied as a predictive system, which allows the reasons for decisions to be analyzed according to different characteristics such as age, gender, population, among others. As a predictive system, computational neuroscience still has a wide field of exploration that needs to be deepened [77].

In application processes have been sought to bring computational neuroscience to the clinical area, correlating and evaluating clinical processes through interoception as a way of investigating holistic functions of the nervous system and dysfunction in disorders of the brain, body, and behavior [58].

The different systems focused on neuroscience are developed as systems for reading and interpreting the brain. There are many models that have emerged in order to analyze the neuronal behavior that exists between the different nervous systems related to the brain. Some of the interpretation systems have been developed using transcranial magnetic stimulation techniques seeking to create non-invasive processes, capable of processing the different layers of information that brain readings can provide [76]. Similarly, Magnetoencephalography presents a brain reading process similar to Transcranial magnetic stimulation, allowing the study of the dynamics and connectivity of brain activity through the interactions of the body and the brain in different media [27].

Some processes such as simplified electromyography allow the electrical pulses generated by the nervous system to be transmitted to electrically analyze to transfer into information, identifying and classifying the different types of pulse and signals that can be generated [35]. One of the most developed processes by different laboratories is magnetic resonance microscopy, which allows brain mapping of very small areas of the brain, generating detailed information on the affected parts and those that are interrelated; Because it is one of the most precise processes, it is one of the most used in neuroscience studies [61].

Another neuronal analysis system is the Magnetic Resonance – Guided Focused Ultrasound, which allows mapping of the nervous system based on ultrasonic resonance, generating images of the affected areas of the brain that react to different waves [31]. As one of the most advanced processes that has been developed in the areas of neuroscience, Brain Computer Interface (BCI) promises to be the new stage of connection and diagnosis of the functioning of the nervous system.

With communication that bypasses normal neuromuscular pathways, a direct connection between the brain and the machine is established, giving real-time data with greater precision and understanding [45]. Many of these methods focus on non-invasive stimulation processes that provide the necessary study information, without resorting to uncomfortable and painful processes that affect the patient's well-being and, in the same way, the taking of results [60].

7. PROPOSED METHODOLOGY

The methodology proposed for this research was of experimental exploratory because a series of tests were carried out in search of a defined result, this methodology was carried out by applying different techniques in this case for the acquisition of signals in search of the improvement of the type of signal acquired.

7.1. QUANTITATIVE DATA:

- Amplitude encephalographic signals.
- Frequency encephalographic signals.

7.2. MATERIALS:

- Electrodes
- Amplifiers
- Protoboard
- Knock it out
- Measuring cables
- Resistances
- Capacitors

7.3. METHODOLOGICAL STAGES:

In the objectives proposed in the investigation, a sensor prototype is developed to measure VEP in order to obtain a noise optimizing device when acquiring the encephalographic signal.

The objectives proposed in the research are met with a cascade methodology, that is, sequential, the steps that were met were:

1. The first specific objective was met by:

   The noise reduction sensor prototype was developed with design by implementing analog filters in the circuit such as band pass, low pass and high pass, the circuit's design used resistors and capacitors in the montage because was necessary decrease the noise acquired in the environment

   The frequencies and amplitudes of encephalographic signals obtained were:

   - Delta signals: 0,1 Hz – 3,99 Hz
   - Theta signals: 4 Hz – 7,99 Hz
   - Alpha signals: 8 Hz – 13,99 Hz
   - Beta signals: 14 Hz – 30 Hz

2. The second specific objective was met by:

   The checkerboard test was developed in C language in JAVA which varied the frequency, amplitude and intensity of the colors in the tables presented in the test.

   The test was implemented in a plugin in the specialized imageJ program because in this program the visualization of the checkerboard is easier for the user.

3. The third specific objective was met by:

   The analysis of the encephalographic signals acquired by the sensor is analyzed by means of digital filters, in this case IIR Filters (Infinite Impulse Response) by the type of response; Because the digital filters help to reduce the noise, the digital filters use corresponding frequencies to divide the EEG signal and with this frequency were the help to find four characteristic brain waves.

4. The fourth specific objective was met by:

   The storage, processing and statistical analysis of the different records generated by the signal reading and capture system, analyzing the arithmetic mean and standard deviation to arrive at a Gaussian analysis, allowing standardization and correlation of each wave type.

5. The fifth specific objective was met by:

   Through data processing and the search for standardized values, perform behavioral comparisons of each of the waves, identifying distinctive patterns that allow them to be related to the standard waves and identify similarities and differences of these.

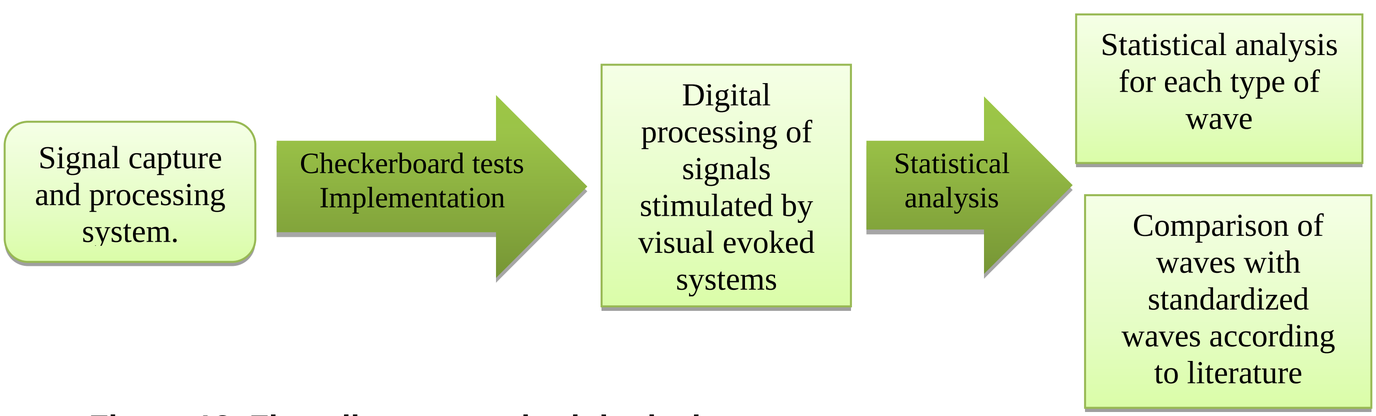


Figure 12. Flow diagram methodological stages

7.4. INSTRUMENTS AND EQUIPMENT

In the stages of the methodology, used different equipment facilitated by the Catholic University of Colombia how:

- Computers: The software for the development of the checkerboard test.
- Oscilloscope: This equipment help acquires and measures the frequencies and amplitudes of the signal.

8. NOVEL CHARACTER OF THE PROJECT

The research innovation was based on the customization of the device prototype.

Currently, medicine teams of evoked potentials are focused on each stimulus.

The device prototype is focused on visual stimuli and the distribution of 50% of equipment noise.

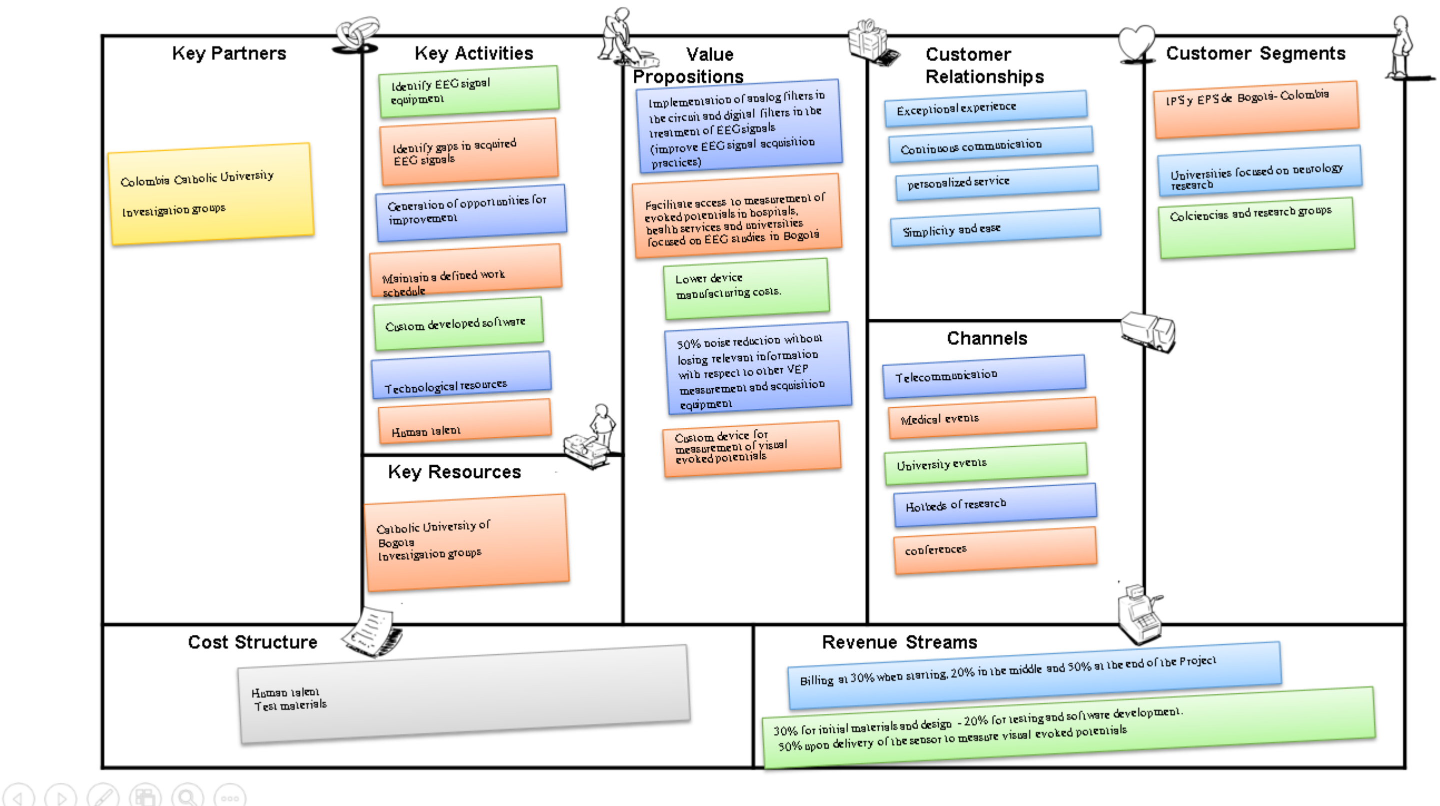


Figure 13. Canvas model sensor prototype for checkerboard visual evoked potentials

9. ANALOG CIRCUIT DESIGN AND SIMULATION

Developing a prototype to noise reduction sensor for evoked visual potentials at low cost requires various methodological steps. In these, the processing and acquisition of encephalographic signals stimulated by visual evoked potentials must be analyzed, looking for a relationship between the type of signal acquired and the reference signals acquired by theoretical investigations. For this process, the stages mentioned below were established.

The acquisition of encephalographic signals must be design in diverse stages of amplification and filtering signals. The signals acquired by sensors for capturing electrical signals can be sampled by the unification of each one of the stages design in order to show a signal without noise or amplification error. For each of the mentioned stages, different circuits were designed in the Proteus® software that allows analyzing the necessary components and simulating the capture and sample of signals.

Two design stages were developed.

9.1 SIGNAL PRE-AMPLIFICATION

At encephalographic signals acquired by electrically conductive sensors (electrodes) is necessary to carry out a pre-amplification stage of the signal that allows acquiring a real value. The encephalographic signals handle values equal to or less than millivolts, so their acquisition and processing are very complex and the presence of noise at the time of acquisition is very high. Taking into account the need to increase the signal and reduce noise, various amplifiers capable of processing the signal for the bandwidth it handles were considered (see table 2.).

Reference	Bandwidth	Impedance consumption
LF353	3 Mhz	High impedance
LF351	4 Mhz	High impedance
LF356	5 Mhz	High impedance
LF412	3 Mhz	Low impedance
CA310	4.5 Mhz	High impedance

LM342	1.2 Mhz	Low impedance
LM348	1 Mhz	Low impedance
LM 1458	1 Mhz	Low impedance
OP07	600 Khz	Low impedance
AD620	120 Khz	Low impedance

Table 2. Commercial Operational Amplifiers.

As acquired signals are low frequency and low impedance, to the project was decided to use the reference operational amplifier AD620, which meets the design needs that managing a frequency of 120 kHz reduces the presence of noise.

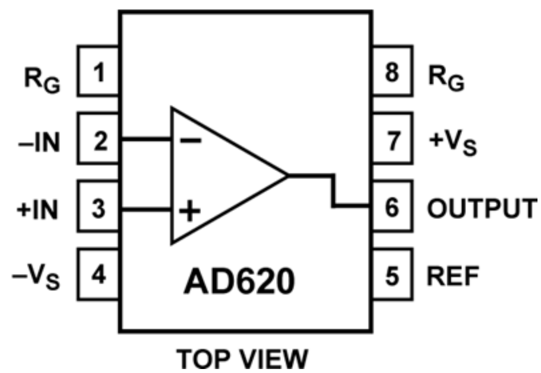


Figure 14. AD620 datasheet.[1]

To define the percentage of gain that the op amp AD620 handles is established by the formula:

$$G = \frac{49.4K\Omega}{Rg} + 1$$

Taking into account the percentage of gain necessary for the signal to be filtered and sampled, a resistance of 2KΩ was established for a gain of 25.7 that adjusts to the filtering and sampling requirements of the signal.

9.1.1 Operational amplifier assembly (simulator). With the defined design requirements, the assembly was carried out using the Proteus® simulator. To simulate the acquisition of data from the encephalographic signals, two signals of 60 Hz at 200uVms were established as input, which resemble the amplitude and frequency of the signals acquired in an encephalographic system.

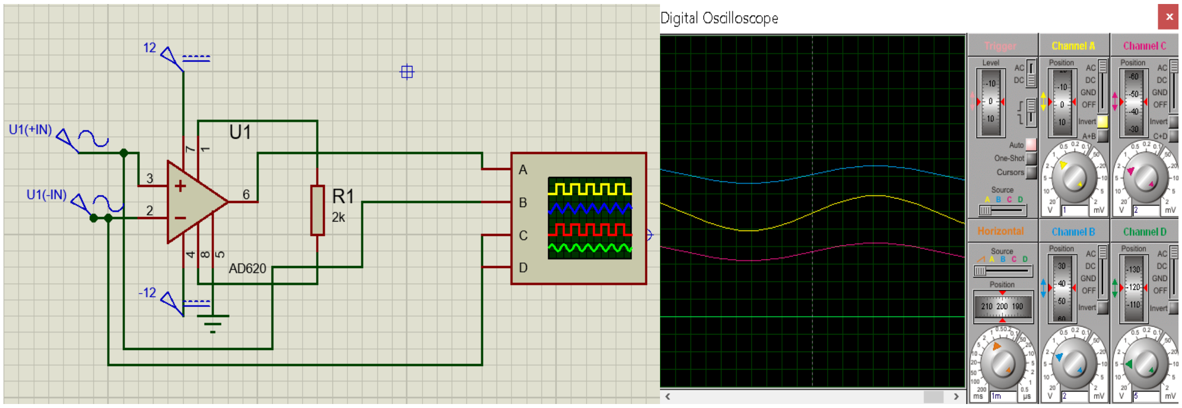


Figure 15. Pre-amplification circuit design AD620.

The amplification of the signal is observed in comparison with the two input signals, complying with the design requirements. Once the amplification is carried, the noise present in the signal must be eliminated, so is necessary filter this.

9.1.2 Encephalographic signal filtering. According to the type of frequency that handles the encephalographic signals, different filtering stages must be designed to classify the signals according to their bandwidth (see table 3.).

Beta signal brain wave 14Hz – 30Hz	**Alpha signal brain wave** 8Hz – 13.99Hz
Theta signal brain wave 4Hz – 7.99Hz	**Delta signal brain wave** 0.1Hz – 3.99Hz

Table 3. Encephalographic signals bandwidth.

For the correct signal filtering, two filtering stages must be developed, one composed of a Notch filter and the other of a low pass filter, that adapt to bandwidth conditions, reducing the presence of signal noise.

9.1.2.1 Notch filter design. The notch filter or band-reject filter is an analog filter to attenuate the signals and reject frequencies of a certain bandwidth as required by the design. As established by the design requirements for capturing encephalographic signals, it is necessary to design an attenuation notch filter for a frequency of 60 Hz, where the presence of noise occurs. For the design of the filter, a fourth order filter was designed with commercial operational amplifiers of reference LF353, which adapt to the already amplified signal that is available from the pre-amplification circuit and allows obtaining the necessary signal by eliminating the present noise.

According to design requirements, the commercial resistors and capacitors used are:

- 2 KΩ
- 4.99 KΩ
- 12.1 KΩ
- 50 KΩ
- 2.65 MΩ
- 1000 pF

With the design components defined, the design and simulation of the Notch filter proceeded.

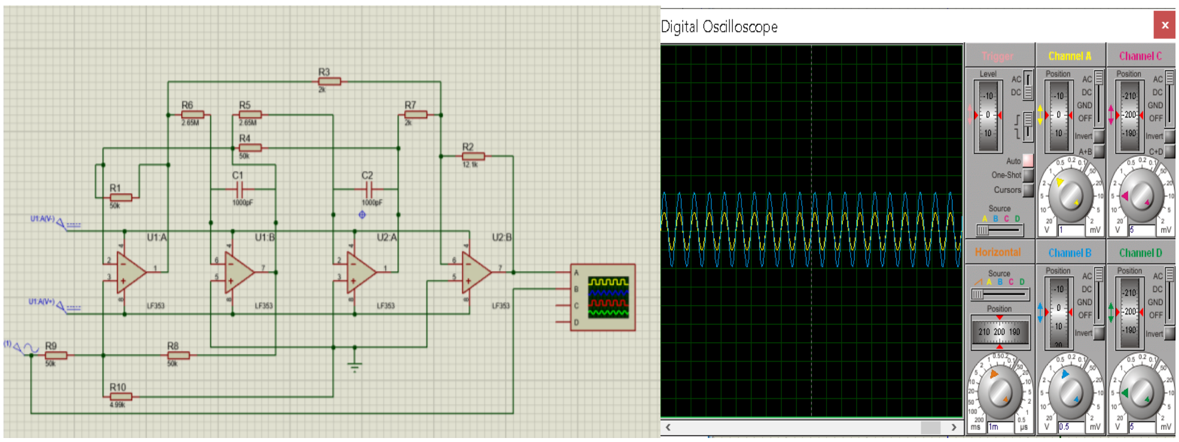


Figure 16. Notch filter design.

The attenuation of the signal is shown, so the filter is eliminating signals with frequencies above 60 Hz, which indicates that the design is optimal.

9.1.2.2 Low pass filter design.Continuing with the filtering stages, a filter must be used to differentiate the low frequency signals, made up of the Alpha (8 Hz - 13.99 Hz) and Beta (14 Hz - 30 Hz) signals. A low pass filter was designed for frequencies below 30 Hz that allowed the signals to be sampled. To determine the profit margin and the filtering frequency, the gain formula of the low pass filters was established, given by:

$$H(s) = \frac{Vout(s)}{Vin(s)} = \frac{1}{1 + sRC}$$

Taking into account the working frequency, the values for the filter were determined. The following elements of commercial values were established:

- 10 KΩ
- 100 KΩ
- 160 KΩ

- 1 MΩ
- 1uF
- 32nF
- 69nF

The circuit was designed with the LF353 amplifier to perform functional and simulation tests.

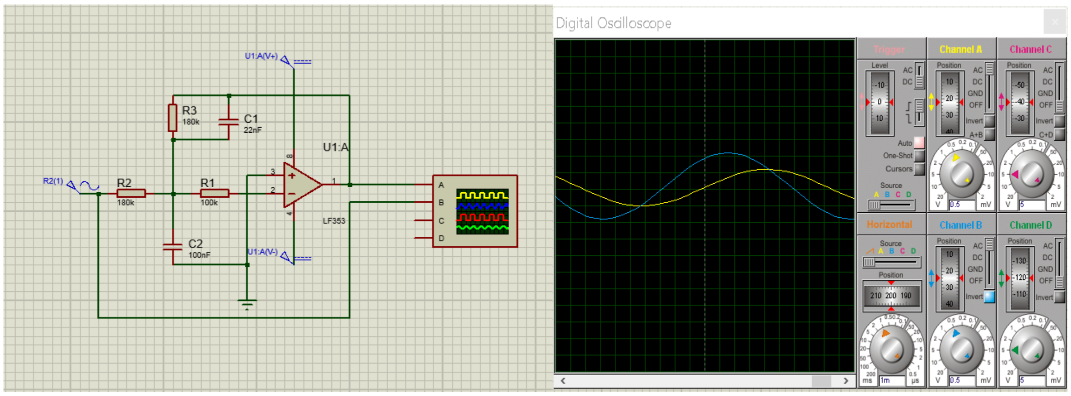


Figure 17. Low pass filter design.

A second-order low pass filter was proposed in order to allow more attenuation of the signal for encephalographic signals. For the design of the filter was decided to use the operational amplifier TL084ACD that allows the handling of an off-set for the signal and reduces the noise present in these.

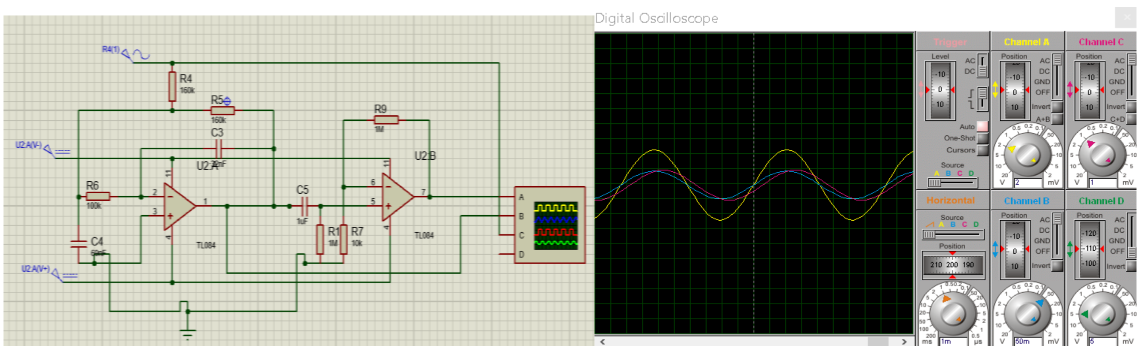


Figure 18. Second order Low pass filter design.

Once all the stages were designed, these were joined into a complete circuit to analyze the complete signals and verify the signal operation.

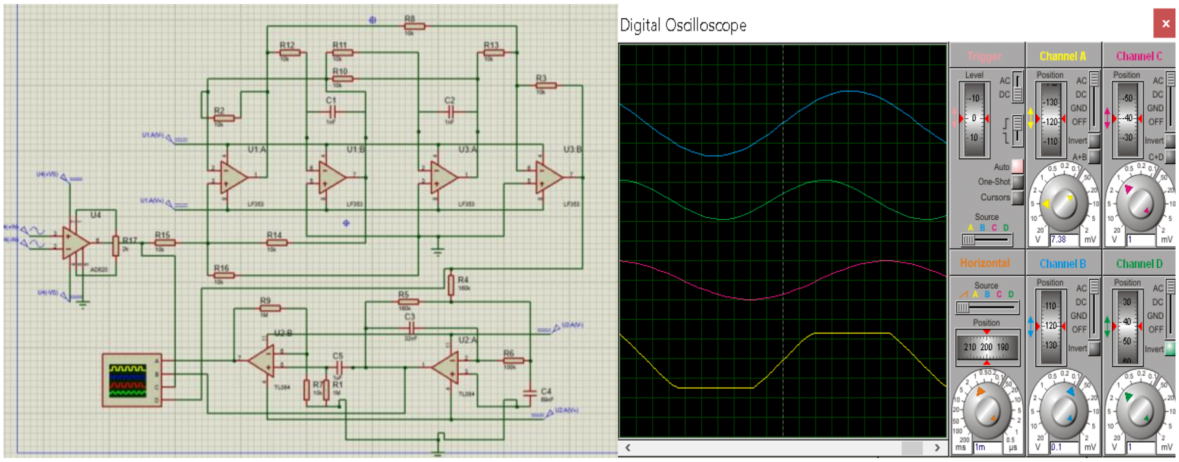


Figure 19. Encephalographic signal acquisition circuit.

10. ANALOG CIRCUIT ASSEMBLY

Different circuits were made to acquire the cleanest encephalographic signal. First two circuits were made, the signal acquired in these circuits had a lot of noise.

10.1 CIRCUIT NUMBER 3.

With the definition of design requirements, the assembly of the circuit will the next step of the design. By the first tests, the circuit was decided to mount a breadboard that would allow all the components to be tested in a laboratory.

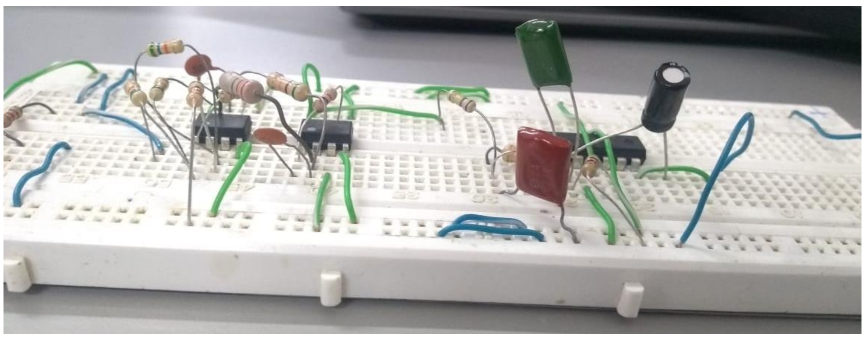


Figure 20. Encephalographic signal acquisition circuit (breadboard mounting).

From the assembly, the signals acquired by electrodes connected to key reference points were tested. Commercial single-use electrical signal acquisition electrodes were used for testing. For the transmission of the signal, a copper cable capable of transmitting the signals captured by the electrodes were used. With the definition of the requirements, the signal capture tests were carried out.

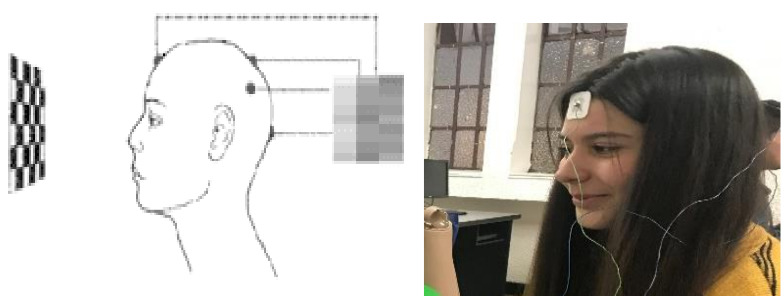
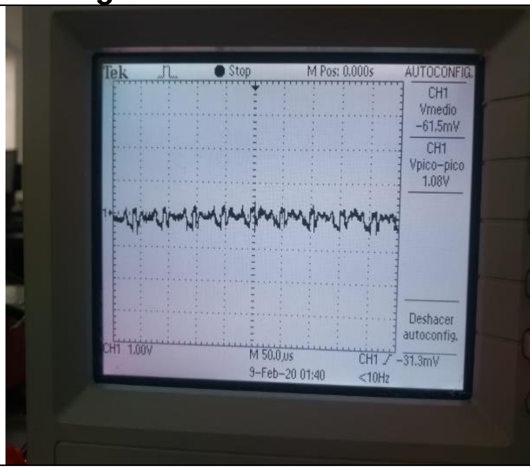
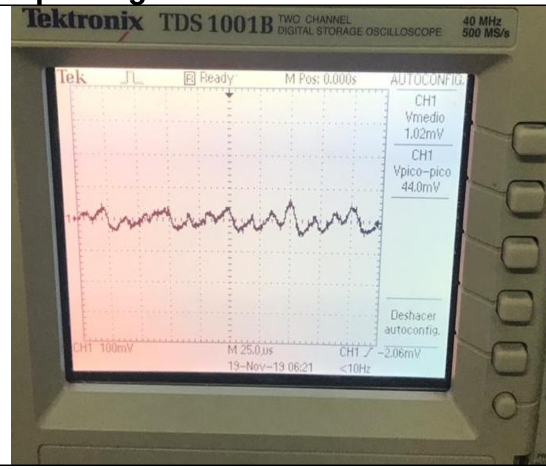
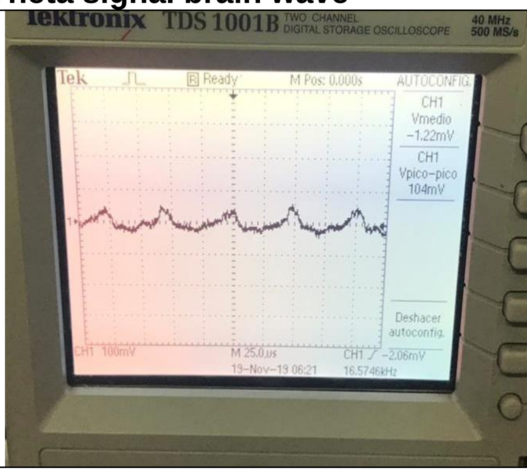


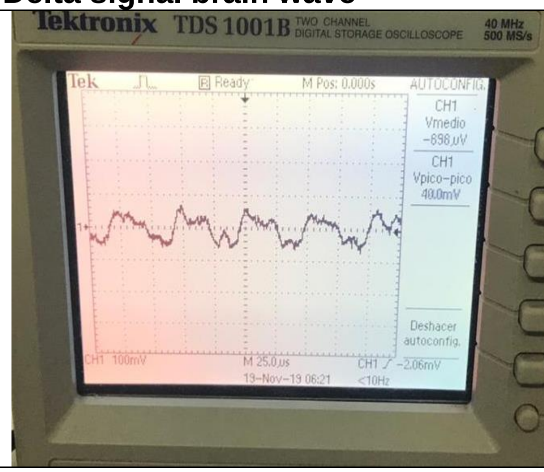
Figure 21. Location electrodes acquisition of encephalographic signals.

The results of the circuit are presented in the following tables. In these tables the four brain waves are recorded, these waves are processed for analysis.

<table>
<tr><th>Beta signal brain wave</th><th>Alpha signal brain wave</th></tr>
<tr><td>


</td><td>


</td></tr>
<tr><th>Theta signal brain wave</th><th>Delta signal brain wave</th></tr>
<tr><td>


</td><td>


</td></tr>
</table>

Table 4. Encephalographic signals.

In this case, the tests were carried out on a 25-year-old patient with a female gender.

In this part of the project, the tests carried out were made only with analog filters, therefore noise is present, the signals were filtered according to the sampling frequency and they were sampled to the point where the signals were obtained according to the concentration state and subsequent drowsiness of the person until reaching the desired signal.

Figure 22. Acquisition of encephalographic signals.

10.2 Circuit number 8.

During the tests, difficulties were encountered due to the presence of noise and a large number of connectors, taking this into account, the circuit was optimized by replacing the notch filter amplifiers with an integrated UAF42AP which has an internal notch filter with a frequency off-set. This allows improving the capture of the signals and their sampling.

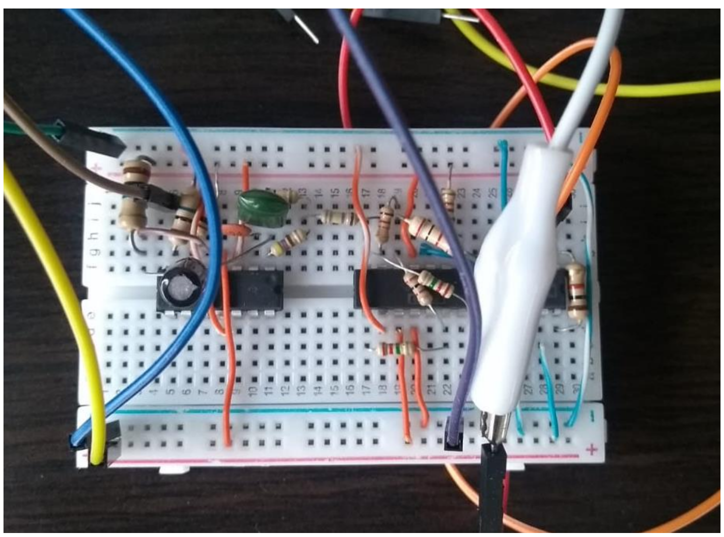


Figure 23. Signal capture circuit optimization (UAF42AP).

The total of the circuits implemented were eight. Different analog filters were implemented in these circuits for maximum noise reduction and it was determined that circuit number 8 was the most optimal because the circuit was the one that captured the signal with the least noise.

The total cost of the prototype is shown below and compared the price (dollars) to other devices that capture brain signals. In annexes are the detailed costs of the materials

Total prototype sensor project to measure visual evoked potentials	397,66 USD
EMOTIV EPOC+ 14 Channel Mobile Brainwear	700 USD
Brainwave Brain Waves Headband	552 USD
NeuroSky (1 Chanel)	1000 USD
OpenBCI (8-16 Channels)	25000 USD

Table 5. Costs prototype sensor project.

In conclusion, the project is the most optimal in cost compared to other EEG devices because some of these devices are created for games, which means that the focus is not on noise reduction, on the other hand, other devices are difficult to access since they are not in Colombia adding shipping cost to the price presented above, meeting the general objective of making a low cost EEG signaling device.

10.3 DESIGN CHECKERBOARD TEST

For the development of tests focused on visual evoked potentials, a CHECKERBOARD test was designed, where the variation of a chessboard is proposed from time to time in order to generate visual stimuli. The JAVA® programming language was used to design the software, in order to create a visual interface that would allow the user to see the variations that appear on the screen to generate the stimuli. The code developed for this was:

“Initially java language is named as “Oak” in 1991, which is designed for the consumer electronic appliances. Later in 1995 the name was changed to Java. Java was developed by James Gosling, a development leader in sun micro system. Oak was redesigned in 1995 and changed the name to java for the development of the applications which can be run over internet. Using the java language, java programs can be embedded in to the html pages. Java is not only limited for the web applications; It is also useful to develop the stand alone applications. Java has a feature called OOPs, which make it more familiar. Object oriented programming replaced the old traditional techniques i.e. procedural programming.”

Taken from: https://ukdiss.com/examples/java-language.php

Version Java (64 bit): 8.0.1110.14
Size Java: 107 MB

JAVA® environment development code:

```
import javax.swing.JFrame;
import javax.swing.JPanel;
import javax.swing.Timer;

/**
 *
 * @author Acosta Hija
 */
public class Vep extends JPanel {

    boolean blanco=true;

    Timer timer;
    Graphics2D g2d ;
    int ancho=30;
    int alto=33;
    int filas=20;
    int columnas=20;


  public void paintComponent(Graphics g) {
    super.paintComponent(g);
     g2d= (Graphics2D) g;

     for(int i=1;i<=filas;i++) {

                for(int j=1;j<=columnas;j++) {
                        blanco=!blanco;
                        if(i==filas/2 && j==columnas/2) {
                                g2d.setColor(new Color(255,255,0));
```

Finally, an ImageJ plugin was obtained that generates variations in the position of the squares on the chessboard, obtaining the desired interface to generate the visual impulses.

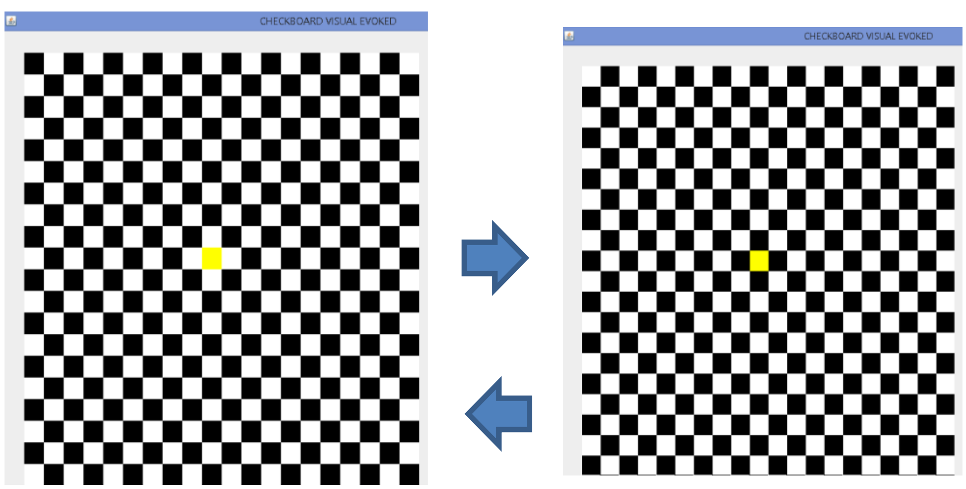


Figure 24. Checkerboard in JAVA® environment.

10.4 DIGITAL SIGNAL PROCESSING

For the digital signal processing system was necessary to design a program for reading and processing analog signals that would allow sampling of the signals in real time. An analog-to-digital data conversion had to be developed to sample the signals and perform their digital processing.

For data capture, a data processing board was necessary to implement, that would allow reading analog data and converting into digital values. The data reading was done using an Arduino® UNO board, which is a microcontroller board based on the ATmega328P, this has five analog inputs for reading data from the circuit, in addition to allowing serial communication to a program for software processing data.

Figure 25. Data acquisition board

A code was designed for data acquisition and Serial communication in the Arduino programming environment. For the tests, two reading port (A0 & A1) were activated, with which the data capture check was performed in real time by the Serial Monitor and the Serial Plotter.

Arduino® environment development code:

```
int out1 = 0;
int out2 = 0;

void setup() {
   // inicializar puerto serie
   Serial.begin(9600);
}

void loop() {
   // leer pines
   out1 = analogRead(A0);
   out2 = analogRead(A1);
   // enviar
   Serial.print(out1);
   Serial.print(",");
   Serial.println(out2);
   // esperar
   delay(20);
}
```

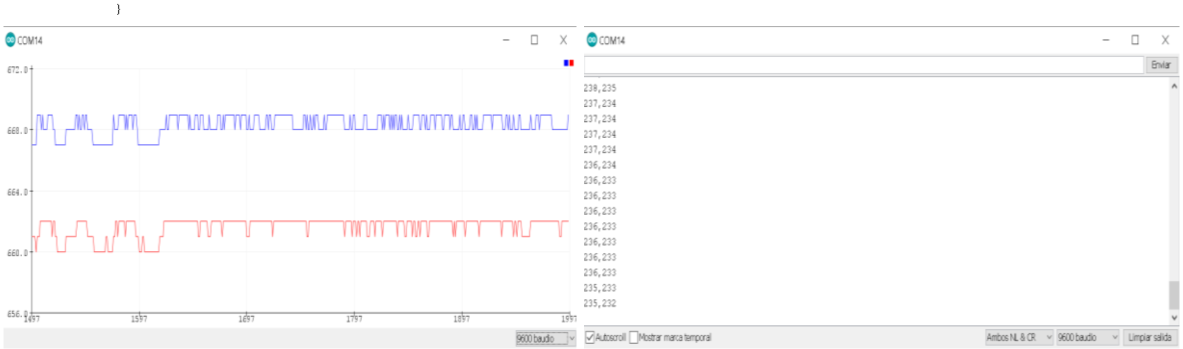


Figure 26. Arduino® Serial Monitor and Serial Plotter.

To improve data capture and sampling, a graphical environment was developed in Matlab® for data capture, processing and sampling. Handling the serial communication, the communication port was established with the Arduino® UNO board and the necessary data processing was performed to sample the signal and reduce the noise present in this. Sampling times were defined through experimentation looking for the one that best suited the captured signals. The control ports were established and the final signal was sampled.

“MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include: Math and computation.”

Taken from:
https://cimss.ssec.wisc.edu/wxwise/class/aos340/spr00/whatismatlab.htm

Version Matlab: 8.3

Matlab® environment development code:

```
global s po co
delete(instrfind({'Port'},{com}));
s = serial(com,'BaudRate',9600,'Terminator','CR/LF');
warning('off','MATLAB:serial:fscanf:unsuccessfulRead');
fopen(s);
po=10;
co=1;
while co<po
tmax = str2double (get(handles.edit1,'string'));
rate = str2double (get(handles.edit2,'string'));
axes(handles.axes1);
axis([0,tmax,-5,5])
l1 = line(nan,nan,'Color','r','LineWidth',2);
l2 = line(nan,nan,'Color','k','LineWidth',1);
xlabel('Tiempo (s)')
ylabel('Voltaje (V)')
title('Signals processing Arduino')
grid on
hold on
v1 = zeros(1,tmax*rate);
v2 = zeros(1,tmax*rate);
i = 1;
t = 0;
tic
while t<tmax
    t = toc;
    a = fscanf(s,'%d,%d')';
    v1(i)=a(1)*5/1024;
    v2(i)=0;
    x = linspace(0,i/rate,i);
    set(l1,'YData',v1(1:i),'XData',x);
    set(l2,'YData',v2(1:i),'XData',x);
    drawnow
```

```
    i = i+1;
end
cla
end
clc;
fprintf('%g s de captura a %g cap/s \n',t,i/t);
```

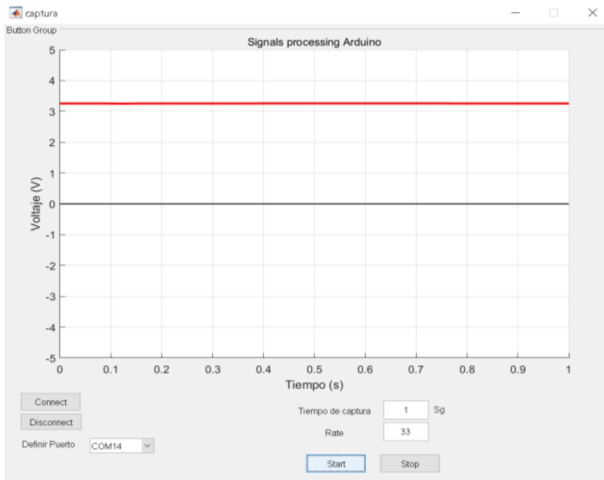


Figure 27. Matlab® Serial Plotter.

10.4 ACQUISITION OF DIGITAL SYSTEM SIGNALS WITH DATA ACQUISITION CIRCUIT.

To capture the encephalographic signals and digital sampling, the circuit was connected to the data acquisition card communicated by the serial port to the sampling program. Sampling was made for each of the signals seeking to adjust the sampling time to the frequency that each signal handles. Sampling calculations were performed experimentally until an optimal signal resolution was achieved.

Figure 28. Acquisition of encephalographic signals (Digital Sampling).

Finally, the acquired signals were classified according to the frequency handled and type of signal for each of the sampled signals (see table 5.).

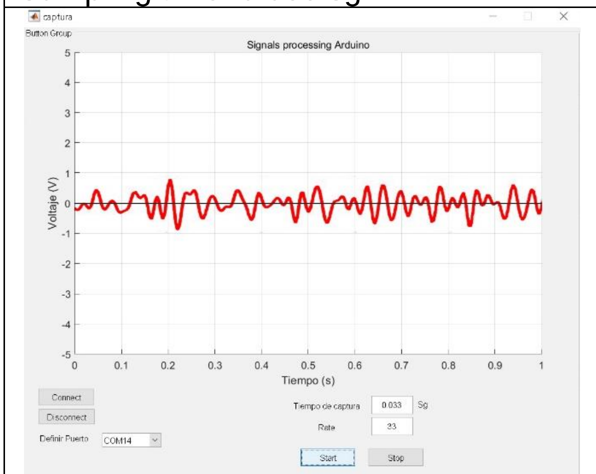
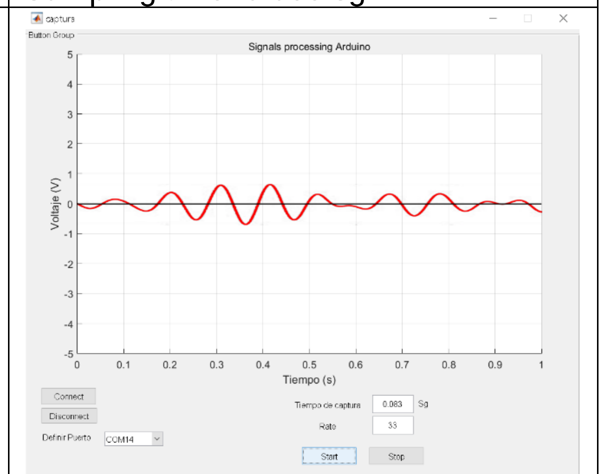
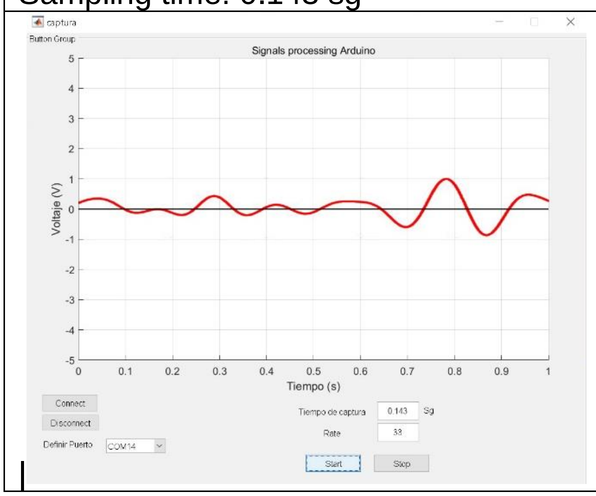
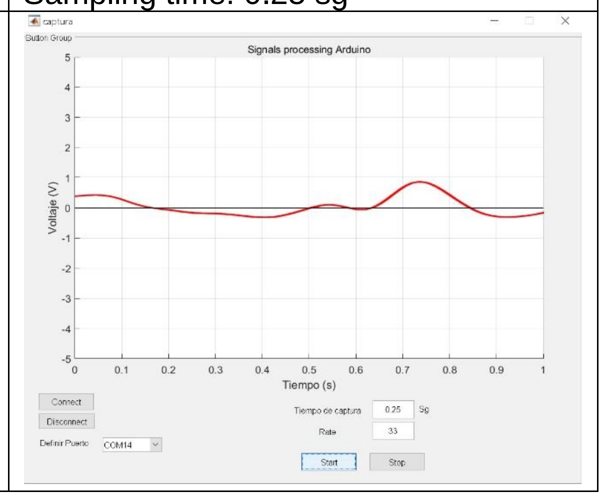
Beta (14-30 Hz)	**Alpha (8-13.99 Hz)**
Sampling time: 0.033 sg	Sampling time: 0.083 sg
	
Theta (4-7.99 Hz)	**Delta (0.1-3.99 Hz)**
Sampling time: 0.143 sg	Sampling time: 0.25 sg
	

Table 6. Encephalographic signals (Digital Sampling).

11. RESULTS

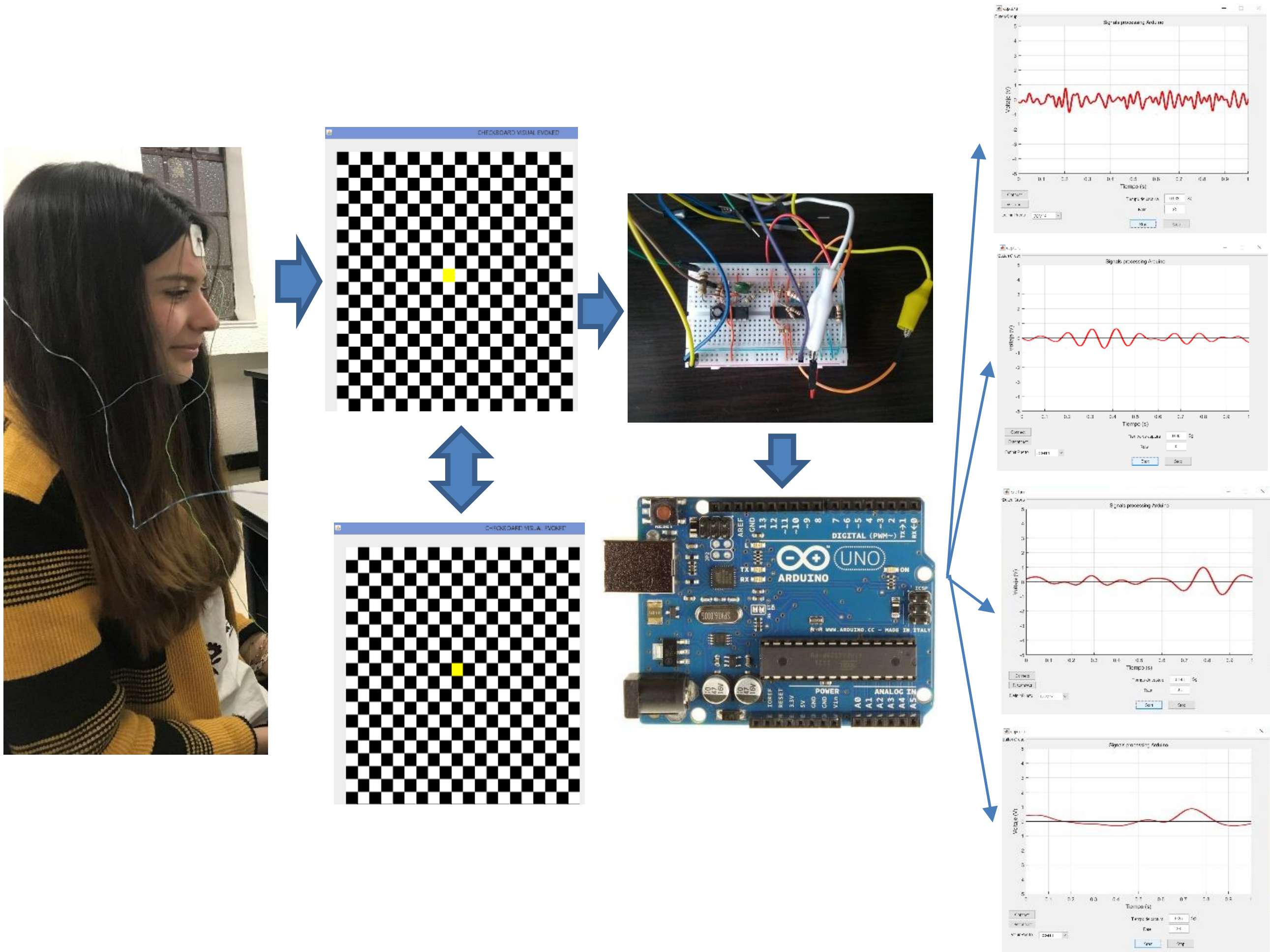


Figure 29. Sensor prototype for checkerboard visual evoked potentials (Model).

To analyze the results, tests were carried out to capture and sample the encephalographic signals using visual impulses generated by the ImageJ plugin designed in Java. The different responses that are presented to the visual stimuli were studied and classified according to the frequency and the signals captured by the system.

The capture system was put together with the visual impulse system so these work continuously generating visual stimuli and carrying out the data reading process by means of the data acquisition card and the capture, amplification, filtering and reading of the encephalographic signals.

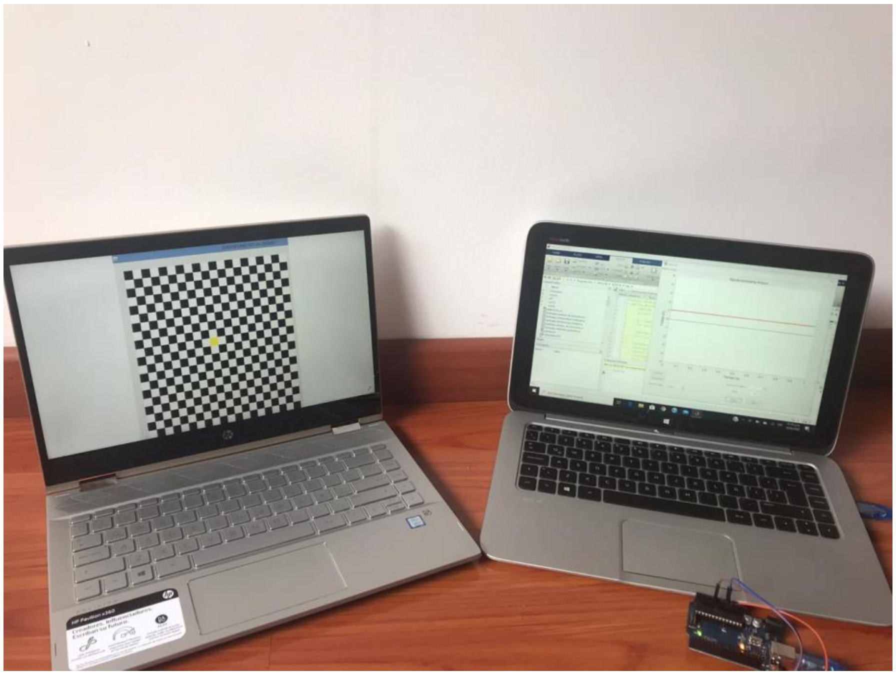


Figure 30. Capture and sampling system together with the visual impulse system.

Using the capture system, the first tests of capture and sampling of encephalographic signals were performed for a person classified between the ages of 20 and 30, without samples of neurodegenerative diseases. For the first tests, the visual impulse system (ImageJ plugin) was not used in order to analyze and classify the responses of the encephalographic signals under normal conditions.

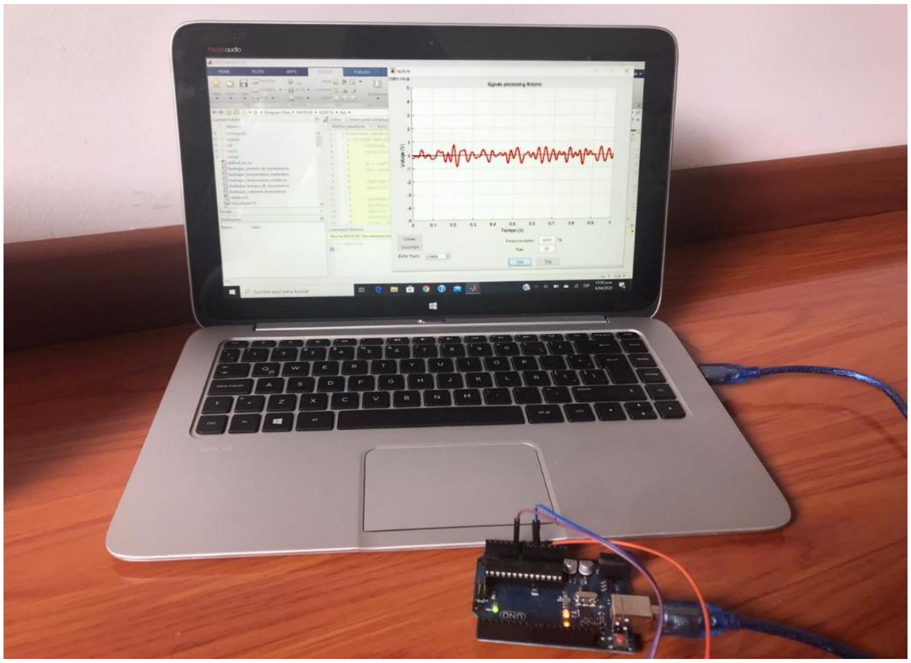


Figure 31. Capture and sampling system.

For a person under normal conditions, the capture signals were classified according to the sampling frequency. The signals were analyzed according to the band representation and were used as a comparison point with the capture signals with the visual impulses.

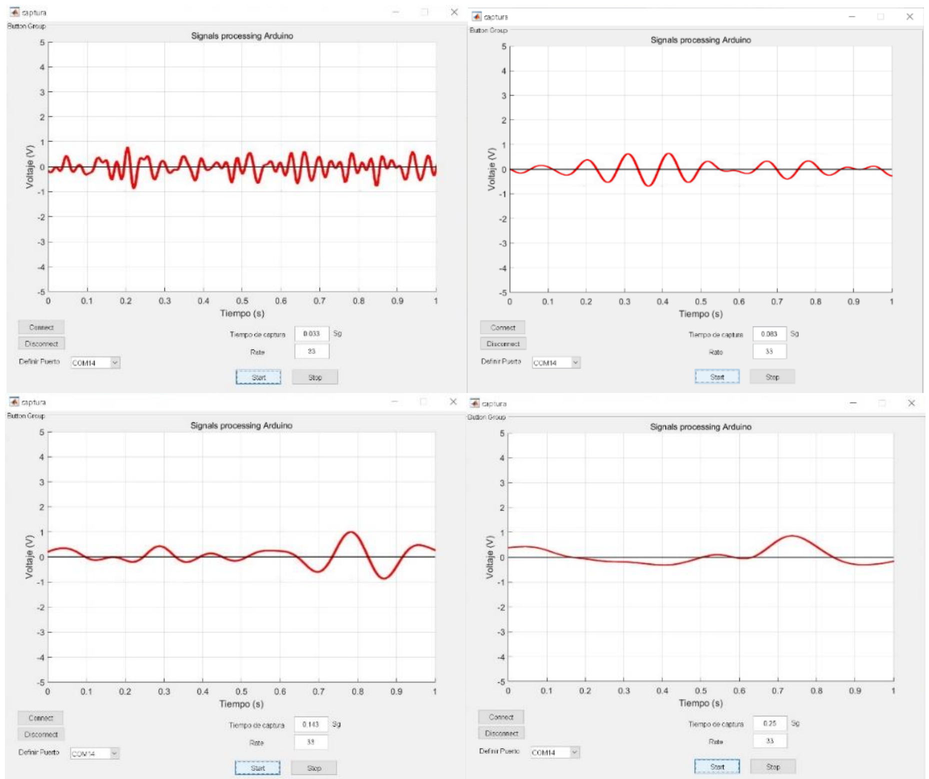


Figure 32. Encephalographic signals (sampling).

Based on the theory, the sampled signals were interpreted according to the sampling frequency to be classified into:

- Beta (14-30 Hz).
- Alpha (8-13.99 Hz).
- Theta (4-7.99 Hz).
- Delta (0.1-3.99 Hz).

With the classification of the waves, the tests were carried out with the same subject and the visual impulse system was applied. For each wave analysis, the effect of the signal depending on the stimulus generated by the visual effect of the change on the board was identified.

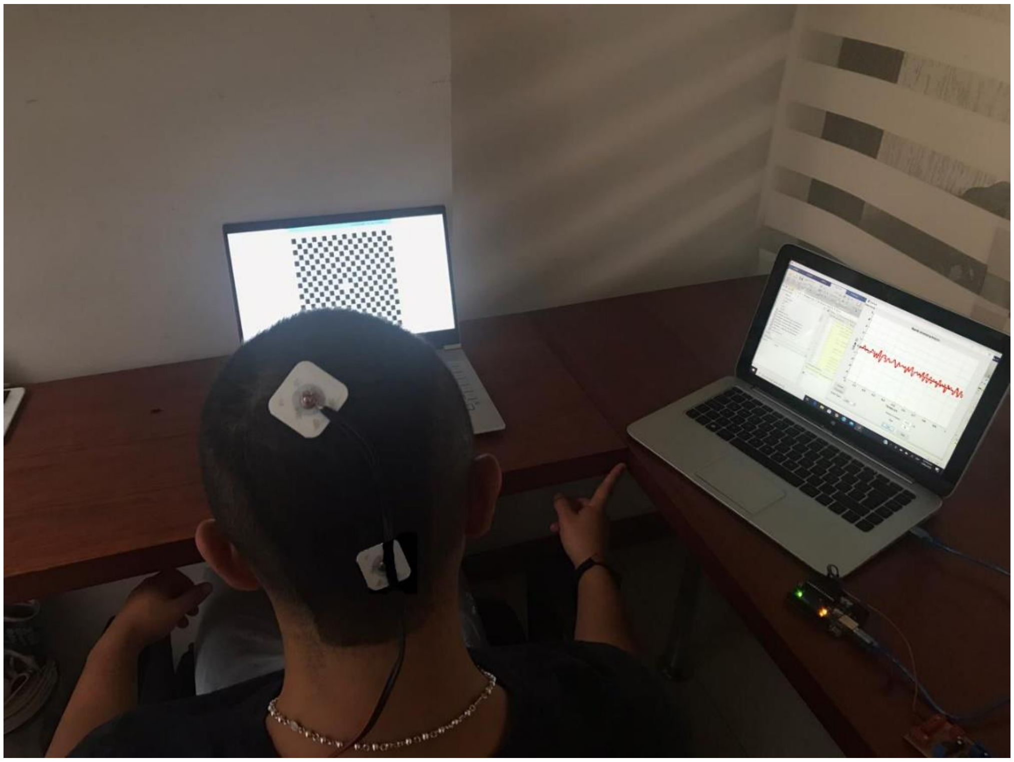


Figure 33. Test subject with visual stimuli.

Beta Wave

The Beta band wave was handled with a sampling frequency of 14 to 30 Hz, Impulse time 3 minutes, the maximum time for the samples was taken as 0.033 sg, the resulting band was:

Figure 34. Beta wave identification.

Alpha Wave

The Alpha band wave was handled with a sampling frequency of 8 to 14 Hz, Impulse time 10 minutes, the maximum time for the samples was taken as 0.083 sg, the resulting band was:

Figure 35. Alpha wave identification.

Theta Wave

The Theta band wave was handled with a sampling frequency of 4 to 8 Hz, Impulse time 20 minutes, the maximum time for the samples was taken as 0.143 sg, the resulting band was:

Figure 36. Theta wave identification.

Delta Wave

The Delta band wave was handled with a sampling frequency of 0 to 4 Hz, Impulse time 30 minutes, the maximum time for the samples was taken as 0.25 sg, the resulting band was:

Figure 37. Delta wave identification.

For each one of the waves sampled with the application of evoked potential type visual stimuli were identified the variations that appear in front of a wave without stimulation and the wave with stimulation.

Variations in amplitude and frequency that are shown in each of the waves were identified for each type of band in their respective frequency. By each wave is possible to identify how visual stimuli create amplitude variations, generating frequency peaks with an amplitude greater than that sampled in signals without stimuli (see table 6.).

Beta	2.2 Vpp	**Beta(visual stimuli)**	2.8 Vpp
Alpha	1.8 Vpp	**Alpha (visual stimuli)**	4 Vpp
Theta	1.6 Vpp	**Theta(visual stimuli)**	3.6 Vpp
Delta	1.4 Vpp	**Delta(visual stimuli)**	3.8 Vpp

Table 7. Peak-to-peak voltage comparison encephalographic signals.

Finally, a comparison was made of the sampling of the encephalographic signals with and without impulses for each of the waves, according to their type of band (see table 7.).

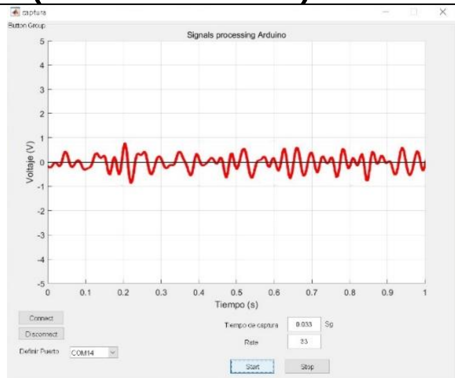
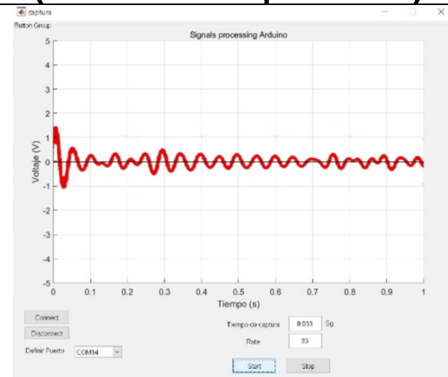
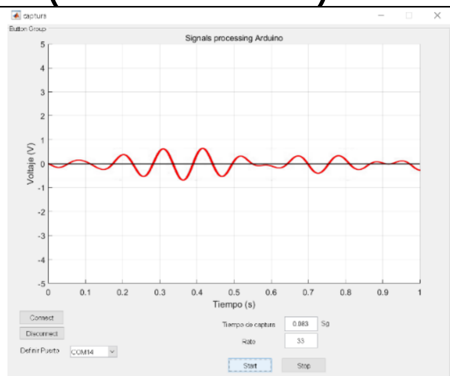
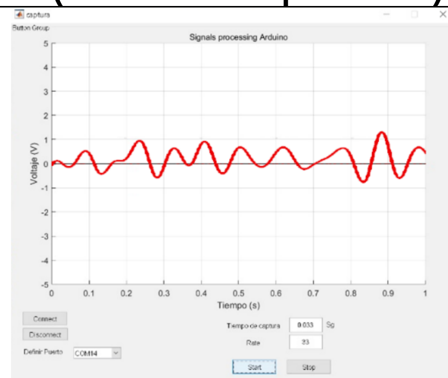
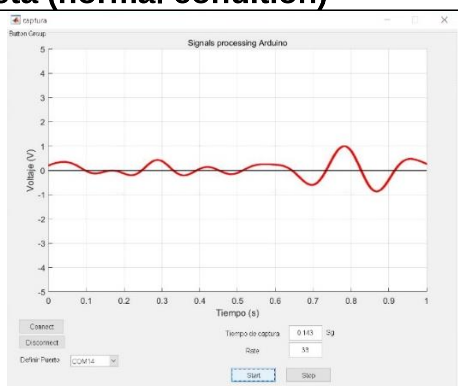
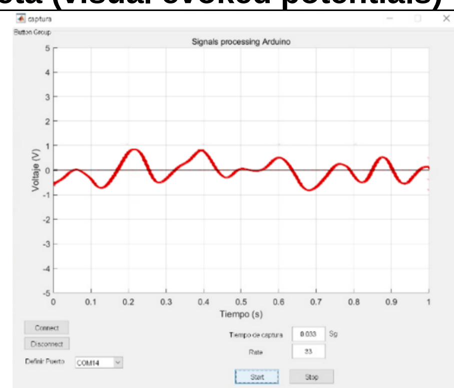
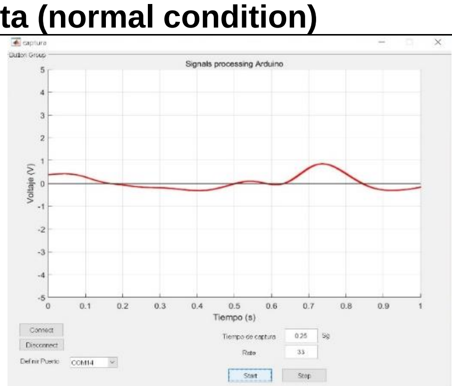
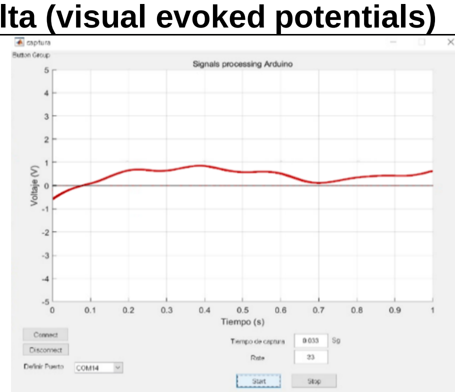
Beta (normal condition)	Beta (visual evoked potentials)
	
Alpha (normal condition)	**Alpha (visual evoked potentials)**
	
Theta (normal condition)	**Theta (visual evoked potentials)**
	
Delta (normal condition)	**Delta (visual evoked potentials)**
	

Table 8. Encephalographic signals (Comparison of visual evoked systems).

One hundred records were carried out, subject to time variations on the stimuli, studying the behavior of the waves subjected to different visual frequencies, determining the variations that occur in the wave amplitude and how the response is.

The records taken are shown in table 8, where the amplitude of the different waves is observed compared to the visual stimuli of variable frequency.

Beta	Alpha	Theta	Delta
0	0,82407903	1,12130446	0,20493542
0,1417817	0,356543	0,26609923	0,16835752
-0,007657	0,37362694	0,12308118	0,21062641
0,02964846	0,4633259	0,24287807	0,28407199
-0,0215653	0,48242399	0,39349177	0,36265763
0,01401932	0,41715304	0,47678498	0,43498443
0,07699961	0,30314128	0,47106254	0,49823009
0,01792272	0,18351351	0,39302784	0,55354061
-0,0077195	0,09039823	0,27382918	0,60295094
0,06360786	0,03983875	0,14509148	0,64765934
0,07725177	0,03356087	0,03179234	0,68736239
0,00479691	0,06351497	-0,0503785	0,72032513
-0,0129291	0,11682354	-0,0949138	0,74388333
0,04371238	0,17991697	-0,1028806	0,75512529

Table 9. Data recording captured waves.

All records are shown in annexes.

Wave behavior shows a variation in amplitude for each stimulus frequency, where a higher frequency shows a more diverse variation in wave responses.

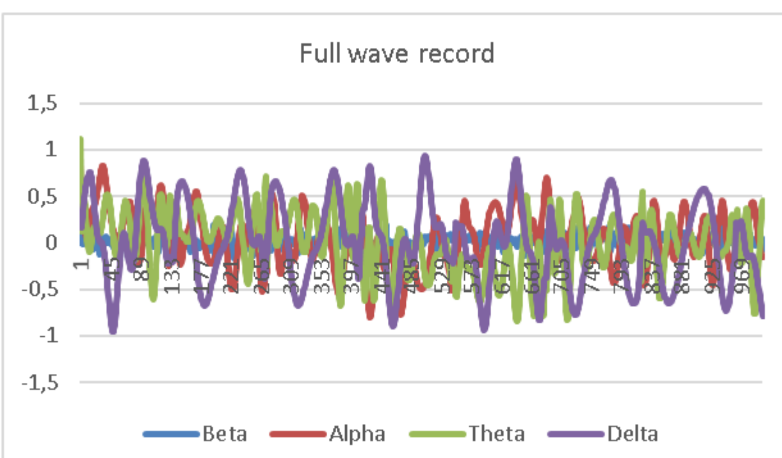


Figure 38. Record of all captured waves.

Due to the large amount of data is necessary to study the system during sampling periods, allowing to better analyze the behavior of the system subjected to stimulus variations and giving a better understanding of this.

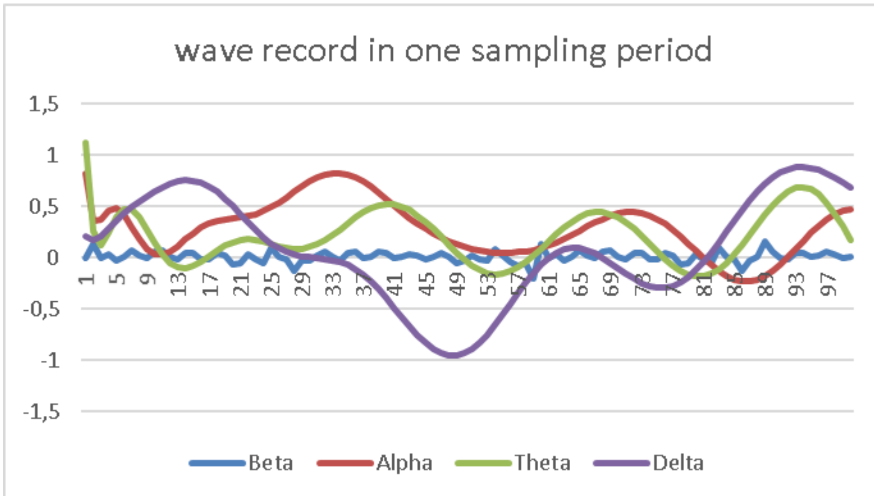


Figure 39. Wave analysis in one sampling period.

For each type of wave, the type of response submitted to the stimuli was studied, analyzing the variations present in the waves and the response for each sampling period.

For beta waves, the variation present in each pulse is observed compared to the different stimuli, where the variable visual stimuli generate a change in the types of signal for each sampling period.

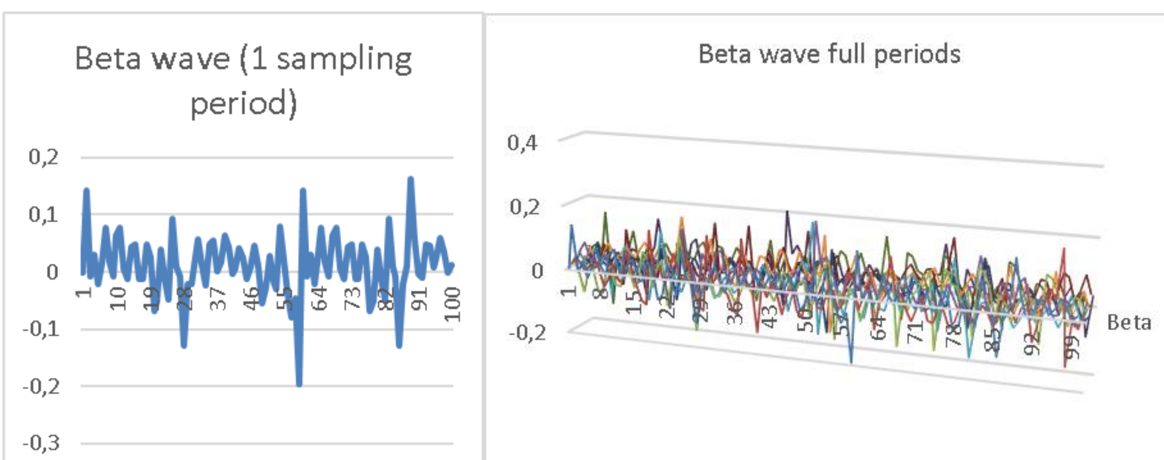


Figure 40. Beta Wave full sampling period.

Similarly, alpha waves show variations compared to variable visual stimuli, showing changes in signal types for each sampling period.

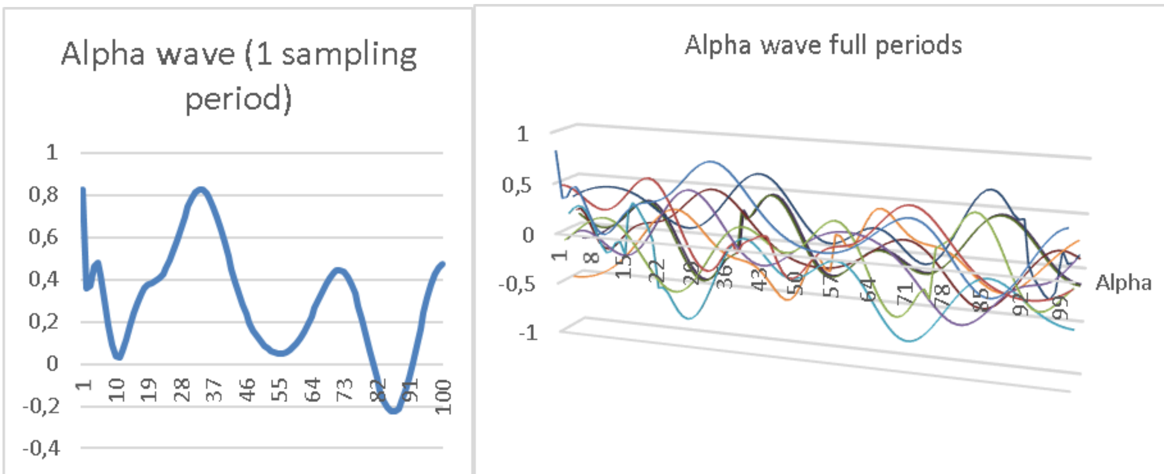


Figure 41. Alpha Wave full sampling period.

Theta waves show a lower amplitude behavior compared to Beta and Alpha waves. Due to the type of wave and the frequency of theta waves, the amplitude variations are less noticeable and the variations show a more linear behavior.

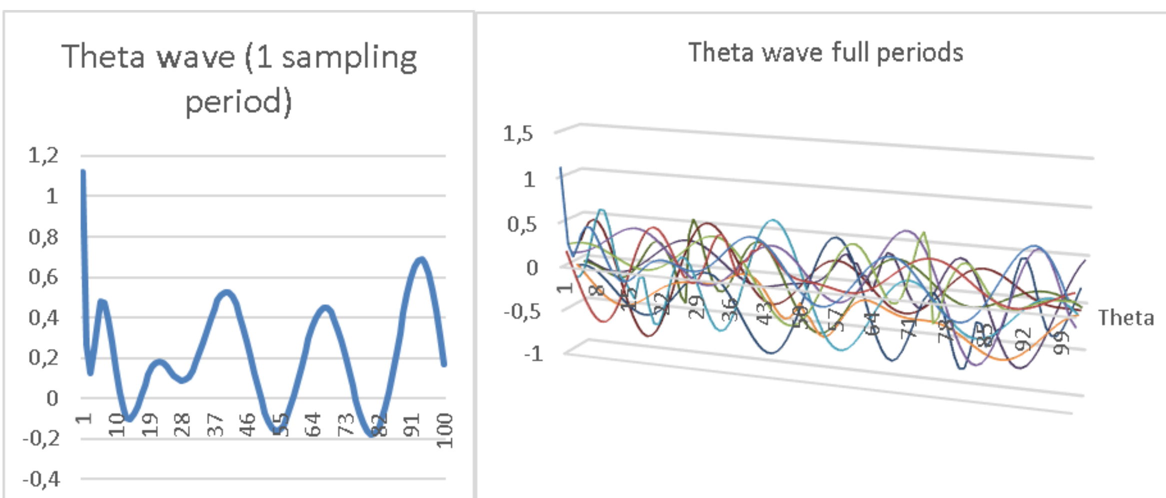


Figure 42. Theta Wave full sampling period.

Finally, the delta waves present an almost null variation, where the stimulus variations do not present a real stimulus in the waves, generating a standardized behavior.

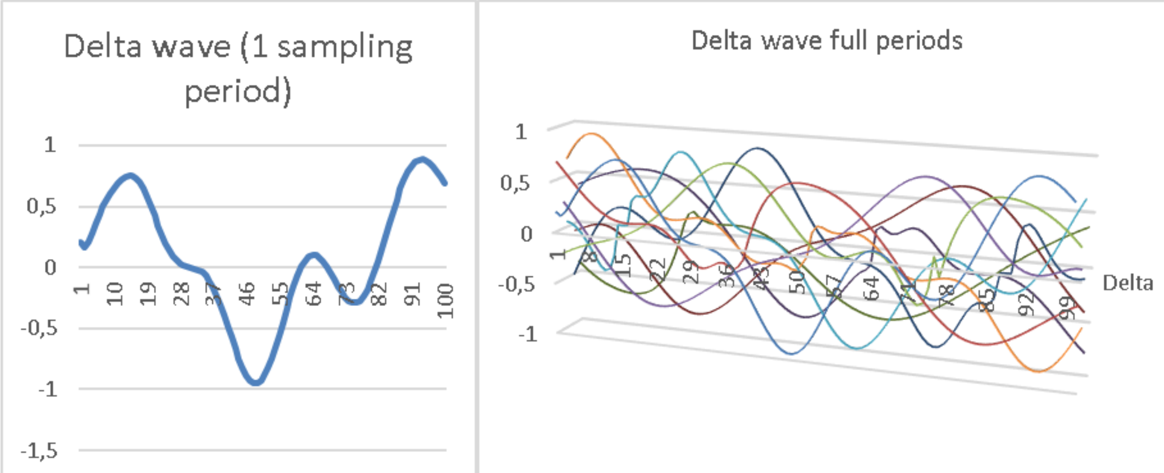


Figure 43. Beta Wave full sampling period.

Finally, the maximum amplitudes of all the records generated are analyzed to determine the behavior and the type of wave, determining the variations and the behavior against the stimuli.

Beta(max R)	Alpha(max R)	Theta(max R)	Delta(max R)
0,1417817	0,82407903	0	0,09039823
0,07699961	0,4633259	0,01401932	0,03983875
0,06360786	0,48242399	0,07699961	0,03356087
0,07725177	0,42565931	0,00165225	0,06351497
0,04775077	0,45445847	0,01665909	0,11682354
0,04764547	0,49262031	0,06429438	0,17991697
0,09316421	0,53892528	0,04446823	0,24137934
0,05651405	0,59089315	-0,0035406	0,29347037
0,04834535	0,64516924	0,00653617	0,33252793
0,05545643	0,6979594	0,04184222	0,35855681
0,06429438	0,7454589	0,01792272	-0,2100912
0,08064358	0,78423115	-0,0077195	-0,176348
0,16257154	0,8115061	0,06360786	-0,1272167
0,05653629	0,82538055	0,07725177	-0,0651022
0,04907467	0,82491579	0,16257154	0,00682862
0,05873198	0,81013781	0,05653629	0,08482083
0,07275568	0,78195354	-0,0023835	0,16476147
0,04912215	0,63584678	0,04603809	0,3750283

Table 10. Data recording (amplitude variation).

All records are shown in annexes.

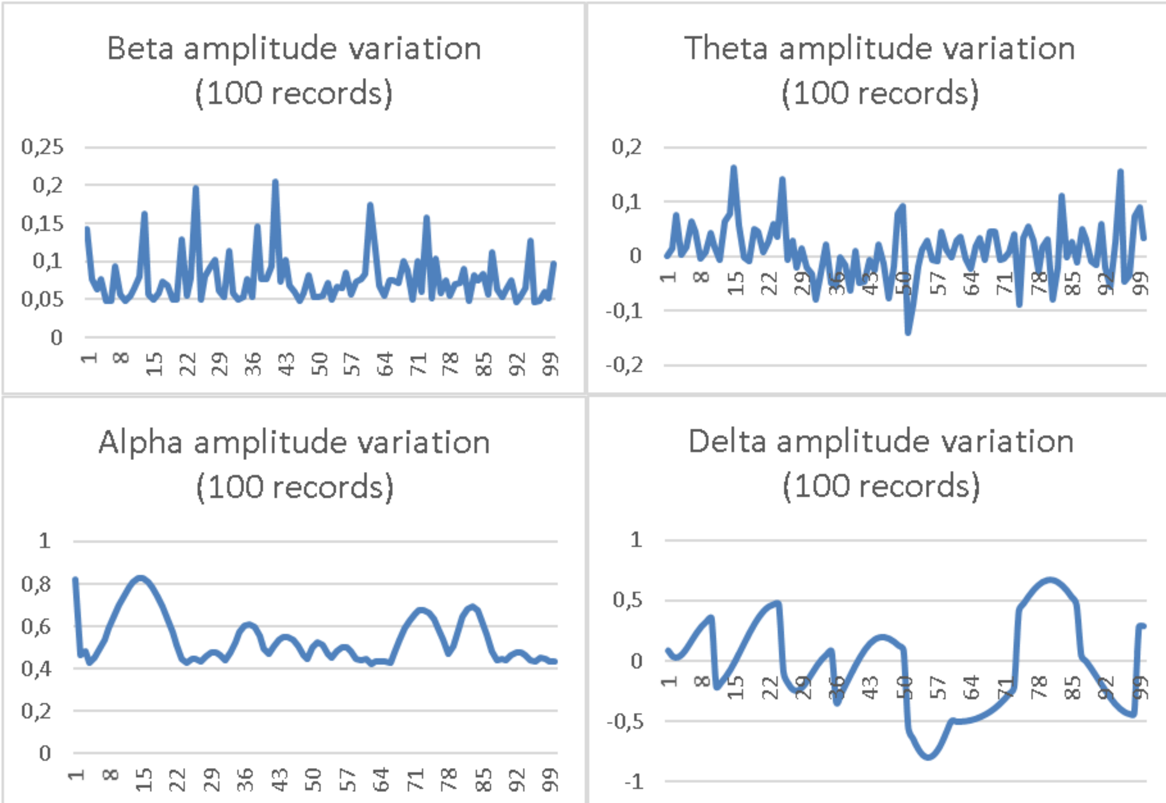


Figure 44. Graphical analysis of wave amplitude variation.

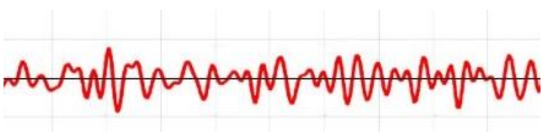
The behavior of the records is observed and how the stimuli affect the type of wave, observing how depending on the wave a more controlled behavior can be presented.

12. VALIDATION OF PROJECT

The validation of the project was carried out by comparing the signals captured with the existing theory on encephalographic waves. For each of the signals, the type of wave and the conditions in which these presented were studied. Next, a comparison is made for each of the waves, analyzing their behavior depending on the user's conditions and how they were presented.

Beta frequency range signal

Normal Conditions



Beta band ideal wave

Vs

Comparison

Visual evoked systems

Figure 45. Beta wave comparison.

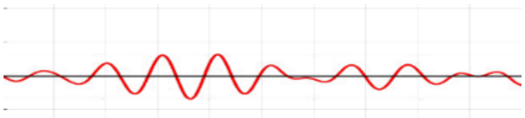
The presence of beta waves occurs in a moment of complete space-time presence, that's meaning when the person is fully active and aware of himself. For the capture of data of the Beta waves, the test subject was subjected to an activation state, this was achieved by means of rapid capture of the data, carried out in a time of seven minutes of the test, where the subject was only subjected to the visual impulses for three minutes in a conscious state.

Data capture was performed with a sampling time of 0.033 sg, adjusting to the sampling frequency of Beta waves, which occur at a frequency of 13 Hz to 30 Hz.

$$F(t) = \frac{1}{0.033sg} = 30.3\ Hz$$

Alpha frequency range signal

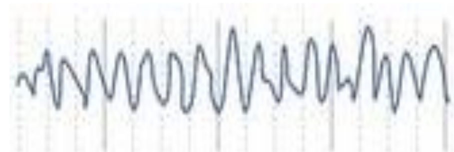
Normal Conditions



Alpha band ideal wave

Vs

Comparison



Visual evoked systems

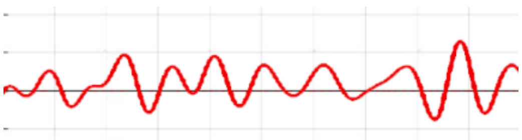


Figure 46. Alpha wave comparison.

The presence of Alpha waves occurs in a moment of relaxation; This occurs in a state where the person is aware but already has low levels of perception regarding space time. The test subject was subjected to a state of relaxation by prolonging the test for 20 minutes.

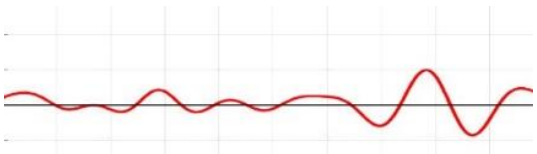
For tests by visual evoked potentials, the subject was subjected to visual stimuli for 10 minutes in a 20-minute test. During the relaxation moment and the presence of low frequency visual stimuli, the variations that were presented in the peaks present in the signal were analyzed, which presented a variation in amplitude compared to the stimulus changes.

Data capture was performed with a sampling time of 0.083 sg, adjusting to the sampling frequency of Alpha waves, which occur at a frequency of 8 Hz to 13 Hz.

$$F(t) = \frac{1}{0.083sg} = 12.05\ Hz$$

Theta frequency range signal

Normal Conditions



Theta band ideal wave

Vs

Comparison

Visual evoked systems

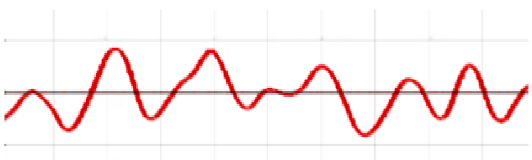


Figure 47. Theta wave comparison.

The presence of Theta waves occurs in a moment of drowsiness; This occurs in a state where the person is still awake but is no longer aware of his around; It is the pre-dream state where the person may still react or may fall completely asleep. To reach this state, the subject was subjected to a 40-minute period of stillness where he was constantly analyzed.

For tests by visual evoked potentials, the subject was subjected to visual stimuli for 20 minutes in a 40-minute test. During the pre-drowsiness moment, with the presence of very low frequency visual stimuli, the variations that were presented in the peaks present in the signal were analyzed, which presented a variation in amplitude compared to the stimulus changes.

Data capture was performed with a sampling time of 0.143 sg, adjusting to the sampling frequency of Theta waves, which occur at a frequency of 4 Hz to 8 Hz.

$$F(t) = \frac{1}{0.143sg} = 6.99\ Hz$$

Delta frequency range signal

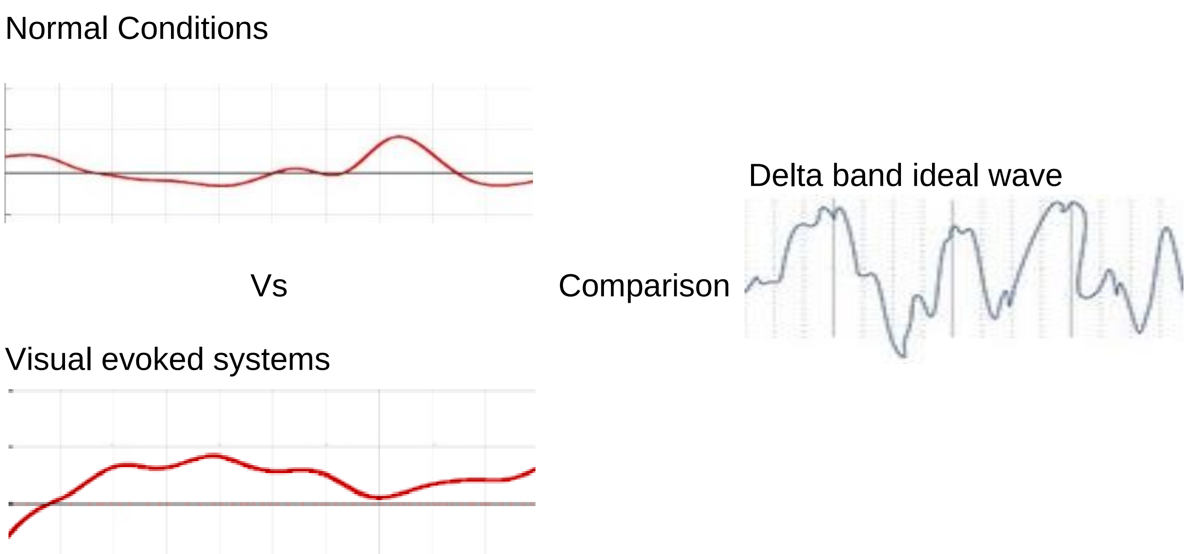


Figure 48. Delta wave comparison.

The presence of Delta waves occurs in a moment of deep sleep; This occurs in a state where the person is completely asleep, disconnected from his exterior, unaware of what is happening around him. To reach this state, the subject was subjected to a 60-minute period of stillness and relaxation in order to take him to deep sleep, where he was constantly analyzed.

For tests by visual evoked potentials, the subject was subjected to visual stimuli for 30 minutes in a 60-minute test. During the pre-deep sleep moment, with the presence of very low frequency visual stimuli, the variations that were presented in the peaks present in the signal were analyzed, which presented a variation in amplitude compared to the stimulus changes.

Data capture was performed with a sampling time of 0.025 sg, adjusting to the sampling frequency of Delta waves, which occur at a frequency of 0 Hz to 4 Hz.

$$F(t) = \frac{1}{0.025sg} = 4\ Hz$$

By statistical analysis, comparisons were made for each type of wave. Taking into account the existing literature, standard waves were established for an adult person, with these, records were taken of the variations that occur compared to the waves captured by the system.

For each type of wave the arithmetic mean and standard deviation are determined, identifying the variations between the standard waves and the waves captured by the system.

Beta		Alpha		Theta		Delta	
Standard Beta	Captured Beta	Standard Alpha	Captured Alpha	Standard Theta	Captured Theta	Standard Delta	Captured Delta
0,1417817	-0,9680264	0,4100719	0,64626314	0,2237460	1,00411348	0,16989196	-0,2410159
-0,007657	0,27236474	0,43790118	-0,229041	0,2856488	-0,3780186	0,16518231	0,39851583
0,02964846	-0,1255807	0,43259941	0,44295247	0,3564772	0,31770601	0,17567184	0,36533264
-0,0215653	-0,0080738	0,39535348	0,02092786	0,4294875	0,21684213	0,19177982	0,12707917
0,01401932	-0,0231396	0,33158723	0,54646444	0,4706787	-0,5804826	0,20594635	0,26352931
0,07699961	-0,0021237	0,25046792	0,12309237	0,4294875	0,48595231	0,21290028	1,10114202
0,01792272	0,09285284	0,16391661	0,16887628	0,2485071	-0,5373373	0,20961224	-0,4514687
-0,0077195	0,02430605	0,08514382	0,46482565	0,0893341	0,86998462	0,19504304	0,49633346
0,06360786	-0,0264969	0,02695576	-0,0370185	-0,0085491	-0,0090657	0,1697736	-0,0961876
0,07725177	0,06622647	0	0,7305681	-0,0545073	0,23612109	0,13558181	-0,1535322
0,00479691	0,10153844	0,01101464	-0,6470337	-0,0613046	0,20204994	0,09501481	0,36250455
-0,0129291	0,00812652	0,06158154	1,24157796	-0,0422375	-0,5305326	0,05099073	0,90230421
0,04371238	-0,0277684	0,14729869	-0,5587184	-0,0093369	0,49922428	0,00645249	-0,7201349
0,04775077	0,04744544	0,25789896	0,90230457	0,0276274	0,01688825	-0,0359132	0,61041873
-0,0129799	0,06545143	0,37788477	-0,2034552	0,0615576	-0,0175654	-0,0738862	0,296233
-0,0131099	-0,0153093	0,48828988	0,42879413	0,0880323	0,13736856	-0,1058516	-0,3811946
0,04764547	-0,0296024	0,56907697	0,02351984	0,1050416	0,16437771	-0,1308721	0,4815908
0,02477063	0,04965306	0,6019404	0,5417776	0,1125653	0,19179989	-0,1487006	-0,1800747
-0,0679098	0,03675063	0,57352748	0,12334803	0,1120767	-0,4872047	-0,1597412	-0,4202808
-0,049536	-0,0793162	0,47827805	0,17232732	0,1060336	0,51037095	-0,1649703	0,48573596
0,03975983	-0,0661066	0,32078662	0,46004389	0,0974002	-0,2542623	-0,1658276	0,82776476
-0,0121609	0,04931795	0,11658515	-0,0198807	0,0892298	0,99845906	-0,1640865	-0,7210754
-0,0491222	-0,0016029	-0,1077334	0,74393889	0,0843246	-0,4178032	-0,161715	0,61940603
0,09316421	-0,0615713	0,09373732	-0,6259185	0,0849802	0,29626225	-0,1607355	-0,2033045
0,01117074	0,08956814	0,49917702	1,20601793	0,0928161	0,21599465	-0,1630903	-0,1927058
-0,0083688	0,01887058	0,84539352	0,38051054	0,1086869	-0,5671969	-0,1705206	0,41854539
-0,1288616	0,00852836	1,09632581	0,77878453	0,1326648	0,4890488	-0,1844626	0,04694798
-0,0217909	-0,0567665	1,23161298	-0,2303129	0,1640838	0,17807703	-0,2059661	-0,6078316
-0,0219327	0,01740271	1,24679692	0,42616033	0,2016327	-0,0574905	-0,2356358	0,57060561
0,02509749	-0,0219327	1,15167014	0,03071881	0,2434826	0,12604706	-0,2735981	-9,245E-06

Table 11. Data recording standard waves and captured waves.

All records are shown in annexes.

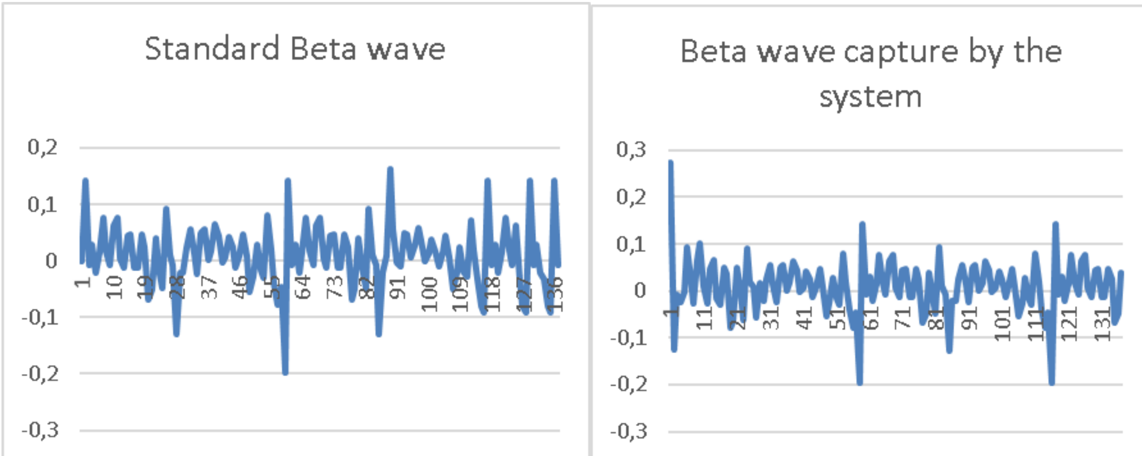


Figure 49. Beta wave analysis.

	Arithmetic average	Standard deviation
Standard Beta	0,008861734	0,055135664
Beta capture by system	0,009235145	0,057394145

Table 12. Statistical analysis beta standard waves and captured waves.

An optimal behavior between functions is determined, with a standard deviation close to each other, represented in the Gaussian function.

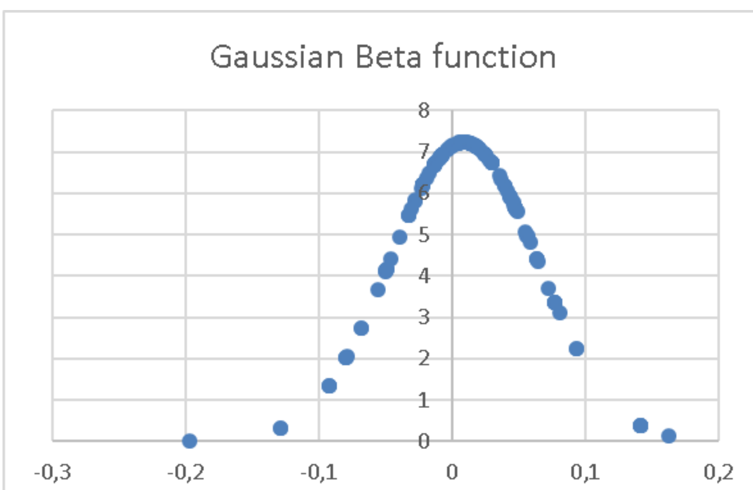


Figure 50. Beta Wave Gaussian Bell Analysis.

A difference of 0.000373411 was obtained between functions, for an arithmetic mean between functions of 0.00904844 and a standard deviation of 0.056264904.

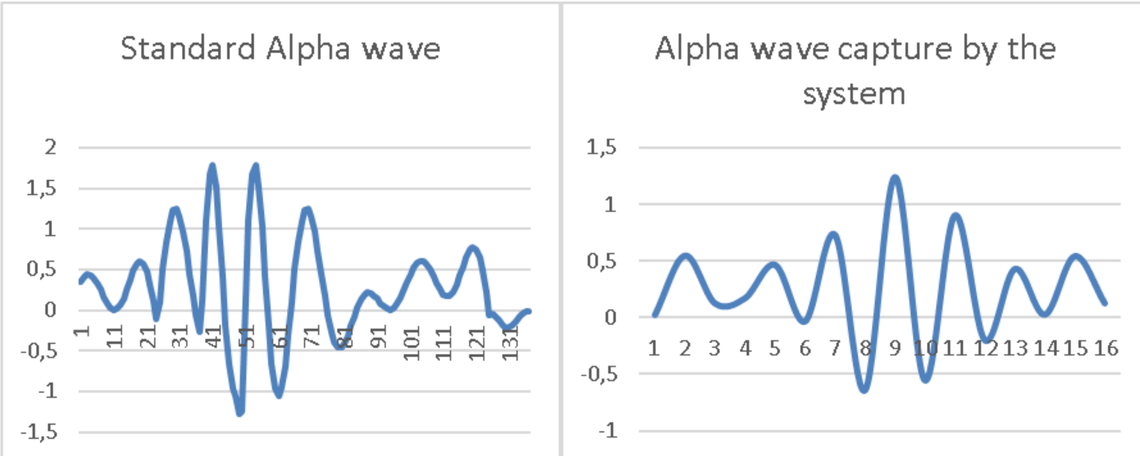


Figure 51. Alpha wave analysis.

	Arithmetic average	Standard deviation
Standard Alpha	0,274952281	0,592325276
Alpha capture by system	0,24186569	0,501926197

Table 13. Statistical analysis Alpha standard waves and captured waves.

An optimal behavior between functions is determined, with a standard deviation close to each other, represented in the Gaussian function.

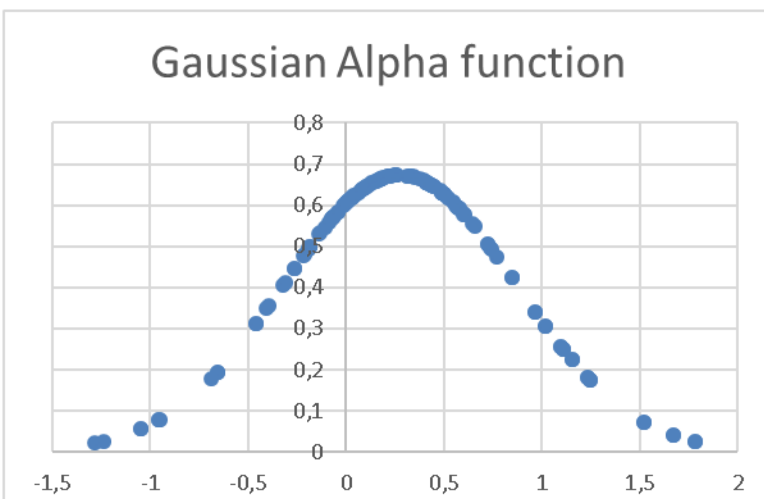


Figure 52. Alpha Wave Gaussian Bell Analysis.

A difference of 0,033086591 was obtained between functions, for an arithmetic mean between functions of 0,258408985 and a standard deviation of 0,547125736.

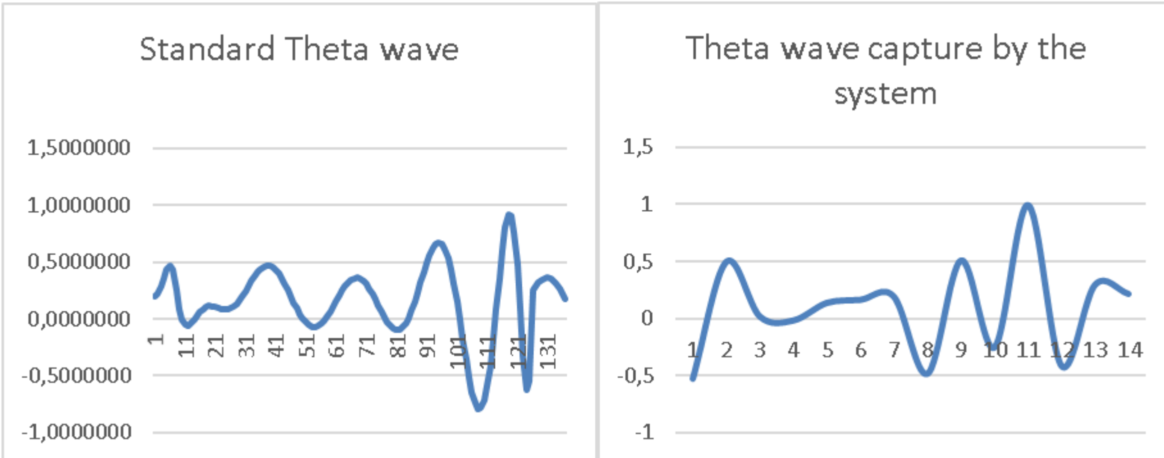


Figure 53. Theta wave analysis.

	Arithmetic average	Standard deviation
Standard Theta	0,1598553	0,3218252
Theta capture by system	0,094526959	0,425826548

Table 14. Statistical analysis Theta standard waves and captured waves.

An optimal behavior between functions is determined, with a standard deviation close to each other, represented in the Gaussian function.

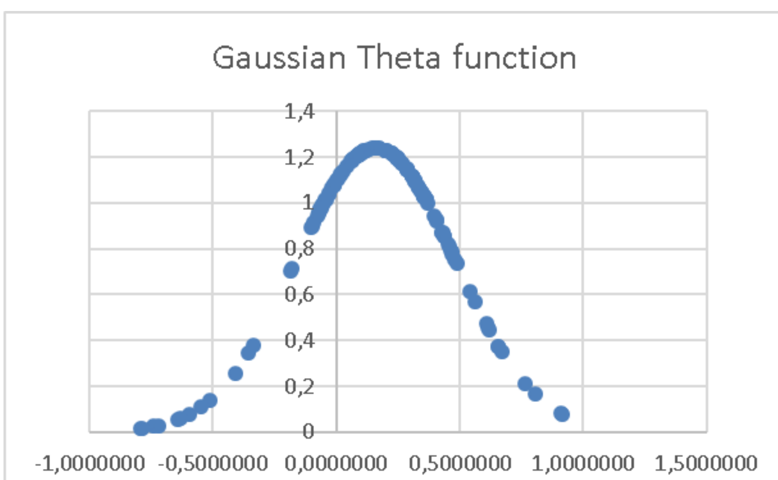


Figure 54. Theta Wave Gaussian Bell Analysis.

A difference of 0,0653283 was obtained between functions, for an arithmetic mean between functions of 0,1271911 and a standard deviation of 0,3738259.

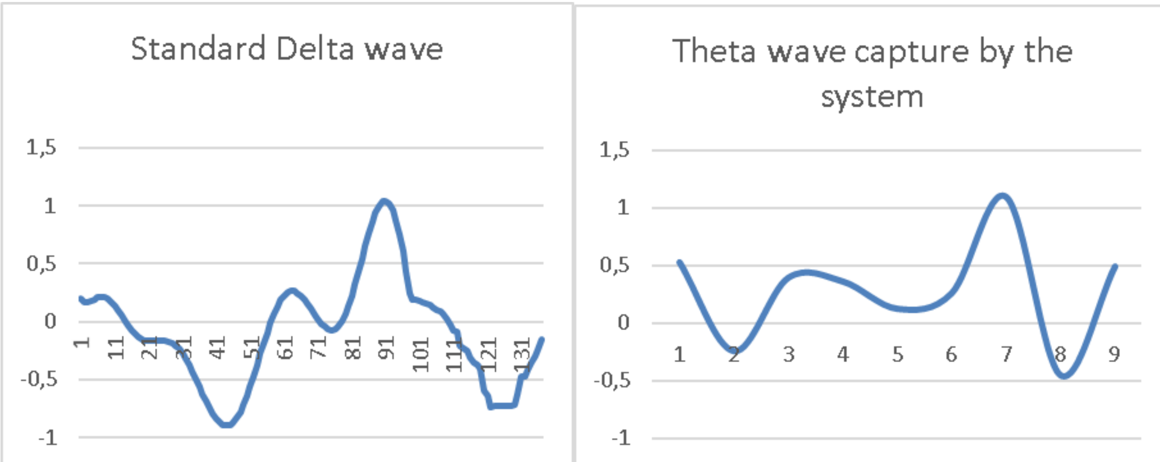


Figure 55. Delta wave analysis.

	Arithmetic average	Standard deviation
Standard Theta	0,086068065	0,458919756
Theta capture by system	0,249594598	0,443306316

Table 15. Statistical analysis Delta standard waves and captured waves.

An optimal behavior between functions is determined, with a standard deviation close to each other, represented in the Gaussian function.

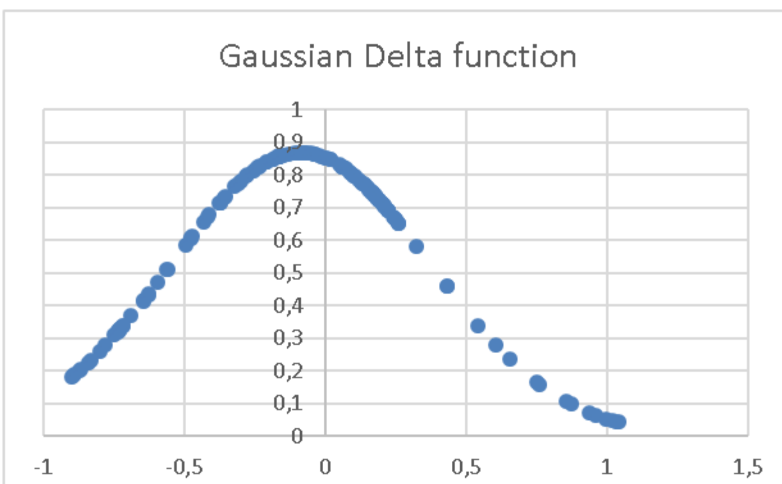


Figure 56. Delta Wave Gaussian Bell Analysis.

A difference of 0,1635265 was obtained between functions, for an arithmetic mean between functions of 0,0817633 and a standard deviation of 0,4511130.

Normal Beta Distribution		Normal Alpha Distribution		Normal Theta Distribution		Delta Normal Distribution	
7,14279072	0,00018963	0,66782382	0,72143318	1,23057775	0,31900713	0,7151467	0,73392897
0,39577463	0,440473382	0,65622082	0,66114926	1,21543476	0,59640992	0,74408637	0,48780231
6,91808719	6,64190591	0,64850906	0,77287773	1,14845369	0,92142259	0,74831821	0,85055199
6,73926916	5,928566727	0,65008186	0,78646298	1,0285735	0,90496264	0,73881923	0,86977092
6,21364012	6,816120564	0,65974738	0,7201491	0,87269902	0,93213619	0,72373008	0,86620496
7,20406012	2,40509998	0,67044724	0,68113314	0,77756305	0,92434564	0,7099912	0,89948016
3,37161452	6,715368656	0,67294376	0,49478234	0,87269902	0,91273817	0,70309773	0,14222087
7,13859652	5,726334407	0,66178847	0,16566049	1,19347289	0,36848247	0,70636902	0,25770906

Table 16. Normal Distribution standard waves and captured waves.

From the analyzes and results shown above, this project shows that the data capture and sampling system by means of the Sensor Prototype for Checkerboard Visual Evoked Potentials was carried out.

Whit all results shows is demonstrated that the Prototype Sensor is capable of capturing, amplifying, filtering and sampling the encephalographic signals, which allows the analysis of the behavior of the signals for different frequencies, achieving the waves in the Beta, Alpha, Theta and Delta bands under the different behavioral circumstance.

SENSOR PROTOTYPE FOR CHECKERBOARD VISUAL EVOKED POTENTIALS (ENCEPHALOGRAPHIC SIGNALS)

ENCEPHALOGRAPHIC SIGNALS ADULT PERSON (NORMAL CONDITIONS)

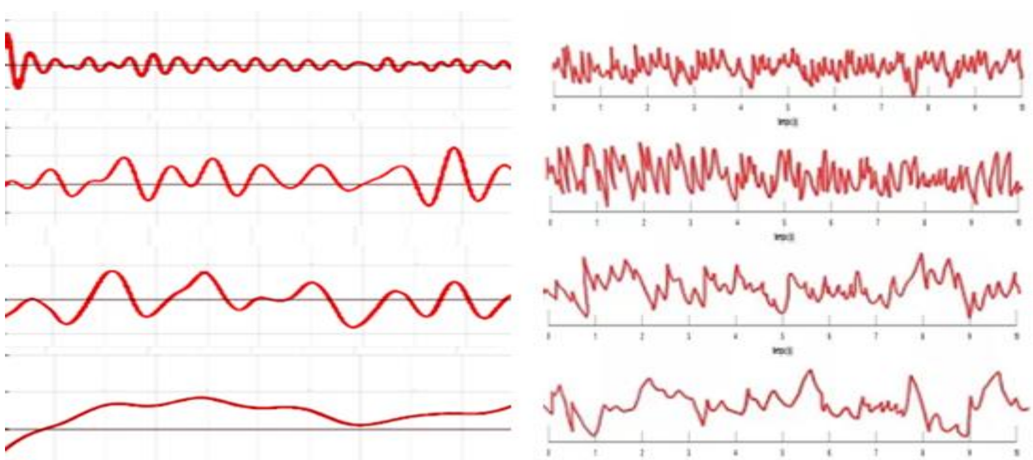


Figure 57. Comparative Wave.

13. CONCLUSIONS AND FUTURE WORKS

Through the design and assembly of analog electrical circuits, divided into an amplification stage designed with an AD620 operational amplifier, a notch-type filter stage designed and optimized by integrated UAF42AP, and a final stage low-pass filtering by means of a TL084ACD operational amplifier, the development of an optimal encephalographic signal sensor was achieved, capable of eliminating external noise from signals captured by dry electrodes located at key points in the head. The sensor delivers a clean signal of electrical signals between the 0.1 Hz and 30 Hz ranges to be recorded and processed by digital data capture and sampling systems.

Data capture was carried out using an Arduino® Uno data acquisition card, with which a serial transfer code was developed with Matlab® software to carry out the signal sampling process. The software performs signal filtering by means of adaptive IIR filters, making a signal processing, improving the capture and sampling of this. The software allows modifying the sampling frequency, establishing signal ranges between 0.1 Hz and 30 Hz, in order to adjust the system to the frequencies that handle the signals encephalographic. Finally, the desired signals were possible to obtain taken these to a digital display system.

The development of a checkerboard test system was achieved through the use of imageJ plugin, developing a variable graphic interface that generates variations in the sampled images through the Netbeans® software. Variations of images at different frequencies generate visual stimuli such as visual evoked potentials, capable of generating variations on the encephalographic signals. The signal variations can be standardized and studied to carry out diagnostic processes of neurodegenerative disorders.

With the digital signal processing the encephalographic signals were standardized, classifying them according to sampling frequency in Beta waves (14Hz - 30Hz), Alpha waves (8Hz - 14Hz), Theta waves (4Hz - 8Hz) and Delta waves (0.1Hz - 4Hz). With the classification of each type of signal was possible to carry out type comparisons and analysis of these when they are subjected to different visual stimuli, observing how disturbances on amplitude appear in different ways for each type of wave, standardizing the conditions and ranges in that each wave is presented.

Through statistical analysis, one hundred different signal registers were standardized for each type of wave. Statistical analyzes were carried out by frequency variations on visual stimuli, generating changes in each wave type for each stored record. The arithmetic mean and standard deviation were identified for each wave type given by, beta arithmetic mean waves of 0.009235145 and standard deviation of 0.057394145, Alpha waves arithmetic mean of 0.24186569 and standard deviation of 0.501926197, waves Arithmetic mean theta of 0.094526959 and standard deviation of 0.425826548, arithmetic mean Delta waves of 0.249594598 and standard deviation of 0.443306316. With the statistical analyzes obtained, the Gaussian analysis was finally carried out for each wave, identifying the representative values of each record.

Through the identification of the standard waves established by the literature, the comparison and validation of the signal capture by the sensor were achieved. Wave behavior was identified by comparing amplitude and frequency with standard waves, giving an average amplitude variation of 0.000373411 for Beta waves, an average amplitude variation of 0.033086591 for Alpha waves, an average amplitude variation of 0.0653283 for Theta waves and an average amplitude variation of 0.1635265 for Delta waves. Finally, by means of the differential analysis of the standard waves and the registered waves, the optimum functioning of the sensor, the capture and sampling system was verified.

Lastly, a better synchronization between the hardware and software could be carried out since in this research two computers plus the sensor were used, because one computer shows the chess test and the other computer captures the encephalographic signals almost realistically. On the other hand, seek to implement different stimuli to the patient and be able to search for supportive diagnoses such as games or educational activities that help to better the anomaly found.

Future jobs includes, in this model, a design with a greater number of electrodes can be made in order to obtain a much broader record and to be able to make different signal captures and make an average to compare whether it is better to have more or fewer electrodes. On the other hand, with a greater number of electrodes, the position of the electrodes could be varied and different tests could be carried out to validate the best way to place the electrodes.

Future jobs includes, different tests could be carried out classifying the population into different groups such as: sex, gender, age, healthy people, people you consider to be sick, profession, tastes since this project can be used in different areas not necessarily in medicine, for example in neuromarketing It is widely used to identify tastes and preferences in population groups.

Future jobs includes, investigation of the encephalographic signals in people with some neurodegenerative disease (Alzheimer's, Parkinson's), for example helping to identify what factors influence accelerating Alzheimer's disease in young people, in Parkinson's being able to identify the areas of the brain where the connection of neurons is already lost and So find the brain areas that suffer in this disease.

Future jobs includes, in children with attention deficit hyperactivity disorder, perform brain signal studies to help the doctor or health personnel make more accurate diagnoses of children with ADHD, since in many cases the child is diagnosed with attention deficit hyperactivity disorder, however, both disorders they are different, a child could suffer from hyperactivity but not necessarily from attention deficit.

Future jobs include, make a software with different characteristics for example: a software that is specified in neurodegenerative diseases, the software using artificial intelligence can include a possible diagnostic support for the doctor in order to speed up the diagnostic processes.

Future jobs include, design a sensor to measure all types of existing evoked potentials, for example visual evoked potentials, auditory evoked potentials, somatosensory evoked potentials, and perform a more complete integration between hardward and software to assist the physician in analysis.

14. BIBLIOGRAPHIC REFERENCES

[1] Adeli, Hojjat, Ziqin Zhou, and Nahid Dadmehr. 2003. “Analysis of EEG Records in an Epileptic Patient Using Wavelet Transform.” *Journal of Neuroscience Methods* 123(1):69–87.

[2] Akil, Huda, Rita Balice-Gordon, David Lopes L. Cardozo, Walter Koroshetz, Sheena M. M. Posey Norris, Todd Sherer, S. Murray Sherman, and Edda Thiels. 2016. “Neuroscience Training for the 21st Century.” *Neuron* 90(5):917–26.

[3] Anon. n.d. “Ion-Selective Electrodes: Proceedings - Google Books.” Retrieved May 23, 2020 https://books.google.com.co/books?hl=en&lr=&id=KgvwAAAAMAAJ&oi=fnd&pg=PA215&dq=studies+with+ion+exchange+calcium+electrodes+in&ots=0W9AmmPeL5&sig=02ER_NhlwP7K-xPCAJbv9w-wqqE#v=onepage&q=studies with ion exchange calcium electrodes in&f=false

[4] Anon. n.d. “ESTIMACIÓN DE POTENCIALES EVOCADOS AUDITIVOS DEL TRONCO CEREBRAL MEDIANTE DESCOMPOSICIÓN MODAL EMPÍRICA.” Retrieved May 23, 2020 (http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S1909-97622008000100005).

[5] Atkinson, John and Daniel Campos. 2016. “Improving BCI-Based Emotion Recognition by Combining EEG Feature Selection and Kernel Classifiers.” *Expert Systems with Applications* 47:35–41.

[6] Banquet, J. P. 1973. “Spectral Analysis of the EEG in Meditation.” *Electroencephalography and Clinical Neurophysiology* 35(2):143–51.

[7] Beaty, Roger E., Paul Seli, and Daniel L. Schacter. 2019. “Network Neuroscience of Creative Cognition: Mapping Cognitive Mechanisms and Individual Differences in the Creative Brain.” *Current Opinion in Behavioral Sciences* 27:22–30.

[8] Bezard, E., A. Pisani, and O. Berton. 2012. “Neuroscience Disease Models.” *Neuroscience* 211:1.

[9] Biederman, J., P. Hammerness, B. Sadeh, Z. Peremen, A. Amit, H. Or-Ly, Y. Stern, A. Reches, A. Geva, and S. V. Faraone. 2017. “Diagnostic Utility of Brain Activity Flow Patterns Analysis in Attention Deficit Hyperactivity Disorder.” *Psychological Medicine* 47(7):1259–70.

[10] Bowman, Lindsay C. 2016. “Developmental Cognitive Neuroscience.” Pp. 309–18 in *The Curated Reference Collection in Neuroscience and Biobehavioral Psychology*. Elsevier Science Ltd.

[11] Braak, Eva, Katherine Griffing, Kimihito Arai, Jürgen Bohl, Hansjürgen Bratzke, and Heiko Braak. 1999. “Neuropathology of Alzheimer’s Disease: What Is New since A. Alzheimer?” in *European Archives of Psychiatry and Clinical Neuroscience*. Vol. 249. Eur Arch Psychiatry Clin Neurosci.

[12] Braak, H. and E. Braak. 1991. “Neuropathological Stageing of Alzheimer-Related Changes.” *Acta Neuropathologica* 82(4):239–59.

[13] Brennan, K. C. and Daniela Pietrobon. 2018. “A Systems Neuroscience Approach to Migraine.” *Neuron* 97(5):1004–21.
[14] Brunner, Dani, Fuat Balci, and Elliot A. Ludvig. 2012. “Comparative Psychology and the Grand Challenge of Drug Discovery in Psychiatry and Neurodegeneration.” *Behavioural Processes* 89(2):187–95.
[15] Carter, Cameron S., Deanna M. Barch, Edward Bullmore, James Breiling, Robert W. Buchanan, Pamela Butler, Jonathan D. Cohen, Mark Geyer, Randy Gollub, Michael F. Green, Judith Jaeger, John H. Krystal, Holly Moore, Keith Nuechterlein, Trevor Robbins, Steven Silverstein, Edward E. Smith, Milton Strauss, and Til Wykes. 2011. “Cognitive Neuroscience Treatment Research to Improve Cognition in Schizophrenia II: Developing Imaging Biomarkers to Enhance Treatment Development for Schizophrenia and Related Disorders.” *Biological Psychiatry* 70(1):7–12.
[16] Casanova, Manuel F., Estate M. Sokhadze, Emily L. Casanova, Ioan Opris, Caio Abujadi, Marco Antonio Marcolin, and Xiaoli Li. 2020. “Translational Neuroscience in Autism: From Neuropathology to Transcranial Magnetic Stimulation Therapies.” *Psychiatric Clinics of North America* 43(2):229–48.
[17] Chamanzar, Alireza, Shilpa George, Praveen Venkatesh, Maysamreza Chamanzar, Lori Shutter, Jonathan Elmer, and Pulkit Grover. 2019. “An Algorithm for Automated, Noninvasive Detection of Cortical Spreading Depolarizations Based on EEG Simulations.” *IEEE Transactions on Biomedical Engineering* 66(4):1115–26.
[18] Curto, Carina and Katherine Morrison. 2019. “Relating Network Connectivity to Dynamics: Opportunities and Challenges for Theoretical Neuroscience.” *Current Opinion in Neurobiology* 58:11–20.
[19] de Lau, Lonneke ML and Monique MB Breteler. 2006. “Epidemiology of Parkinson’s Disease.” *Lancet Neurology* 5(6):525–35.
[20] De Raedt, Rudi. 2020. “Contributions from Neuroscience to the Practice of Cognitive Behaviour Therapy: Translational Psychological Science in Service of Good Practice.” *Behaviour Research and Therapy* 125:103545.
[21] Dimoka, Angelika. 2011. “Brain Mapping of Psychological Processes with Psychometric Scales: An FMRI Method for Social Neuroscience.” *NeuroImage* 54(SUPPL. 1):S263–71.
[22] Fakhruzzaman, Muhammad N., Edwin Riksakomara, and Hatma Suryotrisongko. 2015. “EEG Wave Identification in Human Brain with Emotiv EPOC for Motor Imagery.” Pp. 269–76 in *Procedia Computer Science*. Vol. 72. Elsevier.
[23] Frackowiak, R. 2012. “AS09-01 - Impacts of Neuroscience on Re-Definition of Mental Disorders: A Novel Epistemology.” *European Psychiatry* 27:1.
[24] Fullana, M. A., J. E. Dunsmoor, K. R. J. Schruers, H. S. Savage, D. R. Bach, and B. J. Harrison. 2020. “Human Fear Conditioning: From Neuroscience to the Clinic.” *Behaviour Research and Therapy* 124:103528.
[25] Goodwin, Guy M., Emily A. Holmes, Erik Andersson, Michael Browning, Andrew Jones, Johanna Lass-Hennemann, Kristoffer NT

Månsson, Carolin Moessnang, Elske Salemink, Alvaro Sanchez, Linda van Zutphen, and Renée M. Visser. 2018. “From Neuroscience to Evidence Based Psychological Treatments – The Promise and the Challenge, ECNP March 2016, Nice, France.” *European Neuropsychopharmacology* 28(2):317–33.

[26] Gregory Ashby, F. and Sebastien Helie. 2011. “A Tutorial on Computational Cognitive Neuroscience: Modeling the Neurodynamics of Cognition.” *Journal of Mathematical Psychology* 55(4):273–89.

[27] Gross, Joachim. 2019. “Magnetoencephalography in Cognitive Neuroscience: A Primer.” *Neuron* 104(2):189–204.

[28] Hackel, Leor M. and David M. Amodio. 2018. “Computational Neuroscience Approaches to Social Cognition.” *Current Opinion in Psychology* 24:92–97.

[29] Hjorth, Bo. 1970. “EEG Analysis Based on Time Domain Properties.” *Electroencephalography and Clinical Neurophysiology* 29(3):306–10.

[30] Johnston, Michael V. 2011. “Education of a Child Neurologist: Developmental Neuroscience Relevant to Child Neurology.” *Seminars in Pediatric Neurology* 18(2):133–38.

[31] Jolesz, Ferenc A. and Nathan J. McDannold. 2014. “Magnetic Resonance-Guided Focused Ultrasound. A New Technology for Clinical Neurosciences.” *Neurologic Clinics* 32(1):253–69.

[32] Kasai, Kiyoto, Masato Fukuda, Noriaki Yahata, Kentaro Morita, and Naotaka Fujii. 2015. “The Future of Real-World Neuroscience: Imaging Techniques to Assess Active Brains in Social Environments.” *Neuroscience Research* 90:65–71.

[33] Kesebir, S., R. M. Demirer, and N. Tarhan. 2019. “CFC Delta-Beta Is Related with Mixed Features and Response to Treatment in Bipolar II Depression.” *Heliyon* 5(6):e01898.

[34] Klimesch, Wolfgang. 1999. “EEG Alpha and Theta Oscillations Reflect Cognitive and Memory Performance: A Review and Analysis.” *Brain Research Reviews* 29(2–3):169–95.

[35] Koizumi, Amane, Osamu Nagata, Morio Togawa, and Toshiyuki Sazi. 2014. “The Muscle Sensor for On-Site Neuroscience Lectures to Pave the Way for a Better Understanding of Brain-Machine-Interface Research.” *Neuroscience Research* 78(1):95–99.

[36] Koliatsos, Vassilis E. and Vani Rao. 2020. “The Behavioral Neuroscience of Traumatic Brain Injury.” *Psychiatric Clinics of North America* 43(2):305–30.

[37] Kwako, Laura E., Reza Momenan, Raye Z. Litten, George F. Koob, and David Goldman. 2016. “Addictions Neuroclinical Assessment: A Neuroscience-Based Framework for Addictive Disorders.” *Biological Psychiatry* 80(3):179–89.

[38] Lawrence, Peter J., Kou Murayama, and Cathy Creswell. 2019. “Systematic Review and Meta-Analysis: Anxiety and Depressive Disorders in Offspring of Parents With Anxiety Disorders.” *Journal of the American Academy of Child and Adolescent Psychiatry* 58(1):46–60.

[39] Lehmann, D. and W. Skrandies. 1980. “Reference-Free Identification of Components of Checkerboard-Evoked Multichannel Potential Fields.” *Electroencephalography and Clinical Neurophysiology* 48(6):609–21.
[40] Leibenluft, Ellen. 2017. “Pediatric Irritability: A Systems Neuroscience Approach.” *Trends in Cognitive Sciences* 21(4):277–89.
[41] Lorenzo-ginori, Juan V. 2015. “Universidad Central ‘ Marta Abreu ’ de Las Villas Facultad de Ingeniería Eléctrica Centro de Estudios de Electrónica y Tecnologías de La Información Filtrado de Ruido En Imágenes de Fase Para Aplicaciones Médicas Tesis Presentada En Opción Al Grado Cientí.” (June).
[42] Lynch, Marina A. and Kingston H. G. Mills. 2012. “Immunology Meets Neuroscience - Opportunities for Immune Intervention in Neurodegenerative Diseases.” *Brain, Behavior, and Immunity* 26(1):1–10.
[43] Malfliet, Anneleen, Laurence Leysen, Roselien Pas, Kevin Kuppens, Jo Nijs, Paul Van Wilgen, Eva Huysmans, Lisa Goudman, and Kelly Ickmans. 2017. “Modern Pain Neuroscience in Clinical Practice: Applied to Post-Cancer, Paediatric and Sports-Related Pain.” *Brazilian Journal of Physical Therapy* 21(4):225–32.
[44] Marshall, Scott A., Atul Kalanuria, Manjunath Markandaya, and Paul A. Nyquist. 2013. “Management of Intracerebral Pressure in the Neurosciences Critical Care Unit.” *Neurosurgery Clinics of North America* 24(3):361–73.
[45] McAndrews, Mary Pat, Melanie Cohn, and David A. Gold. 2020. “Infusing Cognitive Neuroscience into the Clinical Neuropsychology of Memory.” *Current Opinion in Behavioral Sciences* 32:94–101.
[46] Miller, Justin B., Jeffrey Cummings, Christin Nance, and Aaron Ritter. 2018. “Neuroscience Learning from Longitudinal Cohort Studies of Alzheimer’s Disease: Lessons for Disease-Modifying Drug Programs and an Introduction to the Center for Neurodegeneration and Translational Neuroscience.” *Alzheimer’s and Dementia: Translational Research and Clinical Interventions* 4:350–56.
[47] Milligan, Kyle, Aishwarya Balwani, and Eva Dyer. 2019. “Brain Mapping at High Resolutions: Challenges and Opportunities.” *Current Opinion in Biomedical Engineering* 12:126–31.
[48] Mittermayer, Christoph. 1999. “On the Determination of Dynamic Errors for Rise Time Measurement with an Oscilloscope.” *IEEE Transactions on Instrumentation and Measurement* 48(6):1103–7.
[49] Miyara, Ing Federico. n.d. *SEMINARIO TALLER SOBRE POTENCIALES EVOCADOS AUDITIVOS NOCIONES TÉCNICAS*.
[50] Möcks, Joachim, Theo Gasser, and Pham Dinh Tuan. 1984. “Variability of Single Visual Evoked Potentials Evaluated by Two New Statistical Tests.” *Electroencephalography and Clinical Neurophysiology* 57(6):571–80.
[51] Mohamad-Mezher, Ahmad. 2007. “Potenciales Evocados CIPSEC (Enhancing Critical Infrastructure Protection with Innovative Security Framework) View Project.”

[52] Mudgal, Shiv Kumar, Suresh K. Sharma, Jitender Chaturvedi, and Anil Sharma. 2020. “Brain Computer Interface Advancement in Neurosciences: Applications and Issues.” *Interdisciplinary Neurosurgery: Advanced Techniques and Case Management* 20:100694.

[53] Narayanan, Manikandan, Jimmy L. Huynh, Kai Wang, Xia Yang, Seungyeul Yoo, Joshua McElwee, Bin Zhang, Chunsheng Zhang, John R. Lamb, Tao Xie, Christine Suver, Cliona Molony, Stacey Melquist, Andrew D. Johnson, Guoping Fan, David J. Stone, Eric E. Schadt, Patrizia Casaccia, Valur Emilsson, and Jun Zhu. 2014. “Common Dysregulation Network in the Human Prefrontal Cortex Underlies Two Neurodegenerative Diseases.” *Molecular Systems Biology* 10(7):743.

[54] National Institutes of Health Consensus Development Conference Report. 2000. “Diagnosis and Treatment of Attention Deficit Hyperactivity Disorder (ADHD).” *Journal of Pharmaceutical Care in Pain and Symptom Control* 8(3):75–89.

[55] Oehler, Martin, Peter Neumann, Matthias Becker, Gabriel Curio, and Meinhard Schilling. 2008. “Extraction of SSVEP Signals of a Capacitive EEG Helmet for Human Machine Interface.” Pp. 4495–98 in *Proceedings of the 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS’08 - “Personalized Healthcare through Technology.”* Vol. 2008. Conf Proc IEEE Eng Med Biol Soc.

[56] Ouss-Ryngaert, Lisa and Bernard Golse. 2010. “Linking Neuroscience and Psychoanalysis from a Developmental Perspective: Why and How?” *Journal of Physiology Paris* 104(6):303–8.

[57] Owen, Michael J. 2014. “New Approaches to Psychiatric Diagnostic Classification.” *Neuron* 84(3):564–71.

[58] Owens, Andrew P., Micah Allen, Sasha Ondobaka, and Karl J. Friston. 2018. “Interoceptive Inference: From Computational Neuroscience to Clinic.” *Neuroscience and Biobehavioral Reviews* 90:174–83.

[59] Packer, Roger J., Jocelyn Villongco, Mark Batshaw, Peter Holbrook, William Davis Gaillard, Phillip L. Pearl, Steven Weinstein, and Edwin Zechman. 2011. “Center for Neuroscience and Behavioral Medicine: An Innovative Administrative Structure and Possible Paradigm for the Future.” *Pediatric Neurology* 44(1):1–9.

[60] Parkin, Beth L., Hamed Ekhtiari, and Vincent F. Walsh. 2015. “Non-Invasive Human Brain Stimulation in Cognitive Neuroscience: A Primer.” *Neuron* 87(5):932–45.

[61] Polimeni, Jonathan R. and Lawrence L. Wald. 2018. “Magnetic Resonance Imaging Technology — Bridging the Gap between Noninvasive Human Imaging and Optical Microscopy.” *Current Opinion in Neurobiology* 50:250–60.

[62] Raichlen, David A. and Gene E. Alexander. 2017. “Adaptive Capacity: An Evolutionary Neuroscience Model Linking Exercise, Cognition, and Brain Health.” *Trends in Neurosciences* 40(7):408–21.

[63] Reardon, Sara and Bob Holmes. 2013. “Mapping Brain Activity Is Neuroscience’s Lofty New Goal.” *New Scientist* 217(2908):20.

[64] Reddy, Harika M., Joshua S. Poole, Gerald A. Maguire, and Stephen M. Stahl. 2020. “New Medications for Neuropsychiatric Disorders.” *Psychiatric Clinics of North America* 43(2):399–413.
[65] Rodríguez-Gómez, Octavio, Adrián Rodrigo, Fátima Iradier, Miguel A. Santos-Santos, Hans Hundemer, Andreea Ciudin, Lena Sannemann, Marissa Zwan, Bridget Glaysher, Anders Wimo, Jaka Bonn, Gunilla Johansson, Isabel Rodriguez, Montse Alegret, Dianne Gove, Susana Pinó, Paloma Trigueros, Miia Kivipelto, Brandy Mathews, Antonio Ciudad, Daniel Ferreira, Christophe Bintener, Miren Gurruchaga, Eric Westman, Mark Belger, Sergi Valero, Peggy Maguire, David Krivec, Milica Kramberger, Rafael Simó, Inmaculada Pérez Garro, Pieter Jelle Visser, Annette Dumas, Jean Georges, Frank Jessen, Bengt Winblad, Craig Shering, Neil Stewart, Laura Campo, and Mercè Boada. 2019. “The MOPEAD Project: Advancing Patient Engagement for the Detection of ‘Hidden’ Undiagnosed Cases of Alzheimer’s Disease in the Community.” *Alzheimer’s and Dementia* 15(6):828–39.
[66] Rodriguez-Mena, D., C. Almarcegui, I. Dolz, L. E. Pablo, and E. Garcia-Martin. 2012. “Application of Electrophysiological Tests in the Study of Neurological Diseases with Visual Involvement.” *Archivos de La Sociedad Espanola de Oftalmologia* 87(10):311–14.
[67] Santiago Rodrigo, Luis de. 2016. “Análisis Avanzado de Señales de Potenciales Evocados Multifocales Aplicados Al Diagnóstico de Neuropatías Ópticas.”
[68] Stavropoulos, Katherine Kuhl Meltzoff. 2017. “Using Neuroscience as an Outcome Measure for Behavioral Interventions in Autism Spectrum Disorders (ASD): A Review.” *Research in Autism Spectrum Disorders* 35:62–73.
[69] Steinglass, Joanna E., Laura A. Berner, and Evelyn Attia. 2019. “Cognitive Neuroscience of Eating Disorders.” *Psychiatric Clinics of North America* 42(1):75–91.
[70] Stern, Emily R. and Stephan F. Taylor. 2014. “Cognitive Neuroscience of Obsessive-Compulsive Disorder.” *Psychiatric Clinics of North America* 37(3):337–52.
[71] Tay, Jonathan, Danuta M. Lisiecka-Ford, Matthew J. Hollocks, Anil M. Tuladhar, Thomas R. Barrick, Anne Forster, Michael J. O’Sullivan, Masud Husain, Frank Erik de Leeuw, Robin G. Morris, and Hugh S. Markus. 2020. “Network Neuroscience of Apathy in Cerebrovascular Disease.” *Progress in Neurobiology* 188:101785.
[72] Tepas, Donald I. and John C. Armington. 1962. “Properties of Evoked Visual Potentials.” *Vision Research* 2(11):449–61.
[73] Thompson, Paul. 2020. “ENIGMA and Global Neuroscience: A Decade of Large-Scale Studies of the Brain in Health and Disease Across More Than 40 Countries.” *Biological Psychiatry* 87(9):S56.
[74] Trist, David G., Adam Cohen, and Alan Bye. 2014. “Clinical Pharmacology in Neuroscience Drug Discovery: Quo Vadis?” *Current Opinion in Pharmacology* 14(1):50–53.

[75] Vaidya, Avinash R., Maia S. Pujara, Michael Petrides, Elisabeth A. Murray, and Lesley K. Fellows. 2019. “Lesion Studies in Contemporary Neuroscience.” *Trends in Cognitive Sciences* 23(8):653–71.
[76] Valero-Cabré, Antoni, Julià L. Amengual, Chloé Stengel, Alvaro Pascual-Leone, and Olivier A. Coubard. 2017. “Transcranial Magnetic Stimulation in Basic and Clinical Neuroscience: A Comprehensive Review of Fundamental Principles and Novel Insights.” *Neuroscience and Biobehavioral Reviews* 83:381–404.
[77] van den Bos, Wouter, Rasmus Bruckner, Matthew R. Nassar, Rui Mata, and Ben Eppinger. 2018. “Computational Neuroscience across the Lifespan: Promises and Pitfalls.” *Developmental Cognitive Neuroscience* 33:42–53.
[78] van den Heuvel, Martijn P., Lianne H. Scholtens, and René S. Kahn. 2019. “Multiscale Neuroscience of Psychiatric Disorders.” *Biological Psychiatry* 86(7):512–22.
[79] Vasterling, Jennifer J., Mieke Verfaellie, and Karen D. Sullivan. 2009. “Mild Traumatic Brain Injury and Posttraumatic Stress Disorder in Returning Veterans: Perspectives from Cognitive Neuroscience.” *Clinical Psychology Review* 29(8):674–84.
[80] Watson, James A., Cormac G. Ryan, Lesley Cooper, Dominic Ellington, Robbie Whittle, Michael Lavender, John Dixon, Greg Atkinson, Kay Cooper, and Denis J. Martin. 2019. “Pain Neuroscience Education for Adults With Chronic Musculoskeletal Pain: A Mixed-Methods Systematic Review and Meta-Analysis.” *Journal of Pain* 20(10):1140.e1-1140.e22.
[81] Wesnes, Keith A. and Chris J. Edgar. 2014. “The Role of Human Cognitive Neuroscience in Drug Discovery for the Dementias.” *Current Opinion in Pharmacology* 14(1):62–73.
[82] Xu, Qing, Wuke Zhang, Linfeng Hu, Jiajiong Wang, and Jia Jin. 2012. “The Development and Research of Bioinformatics in Neuroscience.” *AASRI Procedia* 1:359–64.
[83] Zuluaga, Carolina Posada and Rubén C. Acevedo. n.d. “Estimación de Potenciales Evocados Auditivos Del Tronco Cerebral Mediante Descomposición Modal Empírica.”
[84] ANALOG FILTERS. Basic-Linear-Design.Chapter 8. https://www.analog.com/media/en/training-seminars/design-handbooks/Basic-Linear-Design/Chapter8.pdf
[85] 2004. ANALOG FILTERS. Design of Digital Filters. Chapter 8. https://web.eecs.umich.edu/~fessler/course/451/l/pdf/c8.pdf
[86] 2002. Digital Sampling: A Cultural Perspective. UCLA Entertainment Law Review. https://escholarship.org/content/qt3g70x78x/qt3g70x78x.pdf?t=nnbgzc

15. ANNEXES

Records of all data stored for each wave type

Beta	Alpha	Theta	Delta
0	0,82407903	1,12130446	0,20493542
0,1417817	0,356543	0,26609923	0,16835752
-0,007657	0,37362694	0,12308118	0,21062641
0,02964846	0,4633259	0,24287807	0,28407199
-0,0215653	0,48242399	0,39349177	0,36265763
0,01401932	0,41715304	0,47678498	0,43498443
0,07699961	0,30314128	0,47106254	0,49823009
0,01792272	0,18351351	0,39302784	0,55354061
-0,0077195	0,09039823	0,27382918	0,60295094
0,06360786	0,03983875	0,14509148	0,64765934
0,07725177	0,03356087	0,03179234	0,68736239
0,00479691	0,06351497	-0,0503785	0,72032513
-0,0129291	0,11682354	-0,0949138	0,74388333
0,04371238	0,17991697	-0,1028806	0,75512529
0,04775077	0,24137934	-0,0806688	0,75156399
-0,0129799	0,29347037	-0,0376581	0,73167422
-0,0131099	0,33252793	0,01585231	0,69522689
0,04764547	0,35855681	0,0702742	0,64340034
0,02477063	0,37432314	0,11785433	0,57868408
-0,0679098	0,38423778	0,15330482	0,50461474
-0,049536	0,39325032	0,17400015	0,42539708
0,03975983	0,40590686	0,17982706	0,34546759
-0,0121609	0,42565931	0,17278405	0,26905548
-0,0491222	0,45445847	0,15642532	0,19978812
0,09316421	0,49262031	0,1352354	0,14037722
0,01117074	0,53892528	0,11400677	0,09240927
-0,0083688	0,59089315	0,09727712	0,05625168
-0,1288616	0,64516924	0,08886623	0,03107389
-0,0217909	0,6979594	0,0915369	0,01497317
-0,0219327	0,7454589	0,10679015	0,00518687
0,02509749	0,78423115	0,13479296	-0,0016325
0,05651405	0,8115061	0,17442716	-0,0091051
0,01328761	0,82538055	0,22344112	-0,0208028
-0,0230307	0,82491579	0,27868122	-0,0399421
0,04834535	0,81013781	0,33637751	-0,0691167
0,05545643	0,78195354	0,39245784	-0,1100841
0,00165225	0,7420023	0,44286568	-0,1636207
0,01665909	0,692464	0,48385946	-0,2294527

0,06429438	0,63584678	0,51227495	-0,3062623
0,04446823	0,57477493	0,52573603	-0,3917676
-0,0035406	0,51179514	0,52280414	-0,4828669
0,00653617	0,44921514	0,5030607	-0,5758355
0,04184222	0,38898414	0,46712178	-0,6665605
0,02502027	0,33261969	0,41658772	-0,7507978
-0,011894	0,28118124	0,35393433	-0,8244338
0,00854617	0,23528647	0,28235483	-0,8837364
0,04686228	0,19516346	0,2055639	-0,9255797
0,00945626	0,16072952	0,12757659	-0,9476309
-0,0553065	0,13168599	0,05247547	-0,9484877
-0,0277659	0,10761841	-0,0158208	-0,9277617
0,02852884	0,08809154	-0,073775	-0,8861024
-0,0169564	0,07273057	-0,1184234	-0,8251637
-0,0301436	0,06128139	-0,1475334	-0,7475144
0,08064358	0,05364544	-0,1597188	-0,6565008
0,02029831	0,04988691	-0,1545087	-0,5560683
-0,0393515	0,05021315	-0,132366	-0,4505535
-0,0787335	0,05493058	-0,0946575	-0,3444592
-0,0461097	0,06438175	-0,0435759	-0,2422225
-0,1968854	0,07886945	0,01797949	-0,1479912
0,1417817	0,0985757	0,08655874	-0,0654176
-0,007657	0,12348363	0,15834416	0,00251822
0,02964846	0,15330963	0,22935183	0,05364803
-0,0215653	0,18745333	0,29564101	0,08671131
0,01401932	0,22497055	0,35352141	0,10140312
0,07699961	0,26457366	0,39974803	0,0983727
0,01792272	0,30466098	0,43169396	0,07917393
-0,0077195	0,34337532	0,44749274	0,04617096
0,06360786	0,37868917	0,44614321	0,00240483
0,07725177	0,40851198	0,42757131	-0,0485713
0,00479691	0,43081336	0,39264572	-0,1028798
-0,0129291	0,44375503	0,34314586	-0,1565182
0,04371238	0,44582113	0,28168323	-0,2055617
0,04775077	0,43594094	0,21157918	-0,2463571
-0,0129799	0,4135919	0,13670422	-0,2756997
-0,0131099	0,378876	0,06128602	-0,2909838
0,04764547	0,33256417	-0,0103055	-0,2903198
0,02477063	0,27610134	-0,0737857	-0,2726126
-0,0679098	0,2115716	-0,1251853	-0,2376003
-0,049536	0,14161963	-0,161071	-0,1858484
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-0,0082175	-0,0494914	0,07752722	0,18595931
0,05387969	-0,0816881	-0,0639275	0,21289593
0,02228278	-0,1140556	-0,1690583	0,22688548
-0,0153242	-0,1426664	-0,2199248	0,22059477
0,01200819	-0,1639417	-0,2122922	0,19329876
0,05292445	-0,1749108	-0,1530208	0,1490254
0,05280108	-0,1733915	-0,0565221	0,09433796
0,14595255	-0,1581843	0,05883735	0,03638709
0,04112382	-0,1291177	0,17395105	-0,0184995
0,02412445	-0,0870246	0,27154195	-0,0656423
-0,0472099	-0,0336828	0,33795721	-0,1023234
0,07657927	0,02834932	0,36421174	-0,1277151
0,04442301	0,09590752	0,34635637	-0,1425603
-0,0007481	0,16545588	0,28527284	-0,1487301
0,07693936	0,2333091	0,18606044	-0,1487577
0,09292456	0,29588893	0,05711783	-0,1454158
0,01229256	0,34992852	-0,0909139	-0,1413799
-0,0076086	0,39267273	-0,2462639	-0,1389945
0,04524858	0,42202936	-0,3970828	-0,1401388

0,04513547	0,43666892	-0,532376	-0,1461809
-0,0077002	0,43608578	-0,6427633	-0,1579969
-0,0041868	0,42059346	-0,7210322	-0,1760334
0,0450913	0,39128555	-0,7624893	-0,2003911
0,02966968	0,34993923	-0,7650925	-0,230909
-0,033366	0,29889369	-0,7293997	-0,267238
-0,0214958	0,24089462	-0,6583529	-0,3088932
0,04055897	0,17892686	-0,5569293	-0,3552826
0,01825023	0,11604092	-0,4316999	-0,4057134
-0,0331467	0,05518271	-0,2903245	-0,4593805
0,02164619	-0,0009582	-0,1410288	-0,5153437
0,05260478	-0,0500808	0,00791191	-0,5725031
0,00804884	-0,0903721	0,14865124	-0,6295793
0,04050461	-0,1205749	0,27418975	-0,6851063
-0,0895071	-0,1400186	0,37871412	-0,7374428
0,033843	-0,1486144	0,4578461	-0,7848043

Records maximum amplitude for each type of wave

Beta(max R)	**Alpha(max R)**	**Theta(max R)**	**Delta(max R)**
0,1417817	0,82407903	0	0,09039823
0,07699961	0,4633259	0,01401932	0,03983875
0,06360786	0,48242399	0,07699961	0,03356087
0,07725177	0,42565931	0,00165225	0,06351497
0,04775077	0,45445847	0,01665909	0,11682354
0,04764547	0,49262031	0,06429438	0,17991697
0,09316421	0,53892528	0,04446823	0,24137934
0,05651405	0,59089315	-0,0035406	0,29347037
0,04834535	0,64516924	0,00653617	0,33252793
0,05545643	0,6979594	0,04184222	0,35855681
0,06429438	0,7454589	0,01792272	-0,2100912
0,08064358	0,78423115	-0,0077195	-0,176348
0,16257154	0,8115061	0,06360786	-0,1272167
0,05653629	0,82538055	0,07725177	-0,0651022
0,04907467	0,82491579	0,16257154	0,00682862
0,05873198	0,81013781	0,05653629	0,08482083
0,07275568	0,78195354	-0,0023835	0,16476147
0,06790984	0,7420023	-0,0097955	0,24241457
0,04953604	0,692464	0,04907467	0,31371585
0,04912215	0,63584678	0,04603809	0,3750283
0,12886155	0,57477493	0,00700771	0,4234112
0,05530647	0,51179514	0,02547736	0,45682105

0,07873349	0,44921514	0,05873198	0,47430062
0,19688535	0,43081336	0,03582763	0,47604691
0,04971843	0,44375503	0,1417817	-0,0914865
0,07933774	0,44582113	-0,007657	-0,1846018
0,09208352	0,43594094	0,02964846	-0,2351613
0,10286684	0,45682105	-0,0215653	-0,2414391
0,0621498	0,47430062	0,01401932	-0,211485
0,05260478	0,47604691	-0,0215653	-0,1581765
0,11395567	0,46343875	-0,0325366	-0,095083
0,05747364	0,4389844	-0,0793377	-0,0336207
0,05020928	0,47403767	-0,0296485	0,01847037
0,05286127	0,52788408	0,02156527	0,05752793
0,07709803	0,57269093	-0,0483454	0,08355681
0,05280108	0,60254619	-0,0554564	-0,3401022
0,14595255	0,61207735	-0,0016523	-0,2681714
0,07657927	0,59793861	-0,0166591	-0,1901792
0,07693936	0,55816997	-0,0642944	-0,1102385
0,09292456	0,49358313	0,00979546	-0,0325854
0,20513326	0,4704589	-0,0490747	0,03871585
0,07395847	0,50923115	-0,0460381	0,1000283
0,10234114	0,5365061	-0,0070077	0,1484112
0,06807879	0,55038055	-0,0254774	0,18182105
0,06006791	0,54991579	0,02156527	0,19930062
0,04859506	0,53513781	-0,0140193	0,20104691
0,0579993	0,50695354	-0,0769996	0,18843875
0,08195962	0,4670023	-0,0179227	0,1639844
0,05387969	0,44876168	0,07933774	0,13109844
0,05292445	0,50244239	0,09208352	0,09389438
0,05532702	0,52367211	-0,1417817	-0,5554969
0,07214431	0,51173307	-0,0895071	-0,6436731
0,04963925	0,46854672	-0,0172538	-0,7237617
0,06623666	0,451643	0,0116777	-0,7774424
0,06501304	0,48526496	0,02774629	-0,7986721
0,08493982	0,50196489	-0,0062101	-0,7867331
0,0560083	0,50116668	-0,008852	-0,7435467
0,07389614	0,48323976	0,04419081	-0,6729004
0,07653796	0,44944529	0,01207537	-0,5802816
0,08302957	0,44360565	-0,0025597	-0,4951296
0,17528024	0,44935648	0,02815653	-0,4998162
0,11489586	0,42513464	0,0369233	-0,5001127
0,06843405	0,43180297	-0,0048444	-0,4963253
0,05539344	0,43509808	-0,0220931	-0,4886605
0,07529456	0,43484012	0,01934959	-0,4771806

0,07538617	0,43076271	0,03240554	-0,4617877
0,07187277	0,47970414	-0,0076086	-0,4422249
0,10105204	0,5377402	0,04524858	-0,4181188
0,08918184	0,58884402	0,04513547	-0,3890331
0,04943577	0,6302674	-0,0077002	-0,3545552
0,10083266	0,65966859	-0,0041868	-0,3143865
0,05963716	0,67526501	0,00804884	-0,2684465
0,15719307	0,67595945	0,04050461	-0,2169692
0,05150253	0,66143052	-0,0895071	0,41772169
0,10400291	0,63217941	0,033843	0,47970414
0,05866309	0,58952778	0,05530647	0,5377402
0,07461318	0,53556406	0,02776586	0,58884402
0,05561063	0,47303891	-0,0285288	0,6302674
0,07024573	0,504845	0,01695639	0,65966859
0,07253036	0,58542331	0,03014357	0,67526501
0,08977911	0,64688565	-0,0806436	0,67595945
0,04833641	0,68445777	-0,0202983	0,66143052
0,08209009	0,69484474	0,11171416	0,63217941
0,07590346	0,67637488	-0,001396	0,58952778
0,08301022	0,62967266	0,02684051	0,53556406
0,05567781	0,5599956	-0,0119232	0,47303891
0,11171416	0,48328231	0,04885382	0,05039842
0,0626806	0,43931478	0,03151752	0,00133485
0,05254438	0,44775125	-0,0098391	-0,0547615
0,06287145	0,44282472	-0,0161591	-0,1155925
0,07491558	0,46662709	0,05946837	-0,1784717
0,04717507	0,4787809	-0,0202273	-0,2404541
0,05306401	0,478467	-0,0556511	-0,2984902
0,06543871	0,46570706	0,02718139	-0,349594
0,12744999	0,44125977	0,15719307	-0,3910174
0,0471919	0,43694546	-0,0462697	-0,4204186
0,04885382	0,45556633	-0,0351808	-0,436015
0,05946837	0,44539683	0,07253036	-0,4367095
0,05165725	0,43666892	0,08977911	0,28481911
0,09714044	0,43608578	0,033843	0,29332444

Comparison of standard wave and sampled wave records

Beta		**Alpha**		**Theta**		**Delta**	
0	1,72292033	0,35214431	-0,0421353	0,1988065	-0,5281209	0,20068075	0,53268571
0,1417817	-0,9680264	0,4100719	0,64626314	0,2237460	1,00411348	0,16989196	-0,2410159
-0,007657	0,27236474	0,43790118	-0,229041	0,2856488	-0,3780186	0,16518231	0,39851583

0,02964846	-0,1255807	0,43259941	0,44295247	0,3564772	0,31770601	0,17567184	0,36533264
-0,0215653	-0,0080738	0,39535348	0,02092786	0,4294875	0,21684213	0,19177982	0,12707917
0,01401932	-0,0231396	0,33158723	0,54646444	0,4706787	-0,5804826	0,20594635	0,26352931
0,07699961	-0,0021237	0,25046792	0,12309237	0,4294875	0,48595231	0,21290028	1,10114202
0,01792272	0,09285284	0,16391661	0,16887628	0,2485071	-0,5373373	0,20961224	-0,4514687
-0,0077195	0,02430605	0,08514382	0,46482565	0,0893341	0,86998462	0,19504304	0,49633346
0,06360786	-0,0264969	0,02695576	-0,0370185	-0,0085491	-0,0090657	0,1697736	-0,0961876
0,07725177	0,06622647	0	0,7305681	-0,0545073	0,23612109	0,13558181	-0,1535322
0,00479691	0,10153844	0,01101464	-0,6470337	-0,0613046	0,20204994	0,09501481	0,36250455
-0,0129291	0,00812652	0,06158154	1,24157796	-0,0422375	-0,5305326	0,05099073	0,90230421
0,04371238	-0,0277684	0,14729869	-0,5587184	-0,0093369	0,49922428	0,00645249	-0,7201349
0,04775077	0,04744544	0,25789896	0,90230457	0,0276274	0,01688825	-0,0359132	0,61041873
-0,0129799	0,06545143	0,37788477	-0,2034552	0,0615576	-0,0175654	-0,0738862	0,296233
-0,0131099	-0,0153093	0,48828988	0,42879413	0,0880323	0,13736856	-0,1058516	-0,3811946
0,04764547	-0,0296024	0,56907697	0,02351984	0,1050416	0,16437771	-0,1308721	0,4815908
0,02477063	0,04965306	0,6019404	0,5417776	0,1125653	0,19179989	-0,1487006	-0,1800747
-0,0679098	0,03675063	0,57352748	0,12334803	0,1120767	-0,4872047	-0,1597412	-0,4202808
-0,049536	-0,0793162	0,47827805	0,17232732	0,1060336	0,51037095	-0,1649703	0,48573596
0,03975983	-0,0661066	0,32078662	0,46004389	0,0974002	-0,2542623	-0,1658276	0,82776476
-0,0121609	0,04931795	0,11658515	-0,0198807	0,0892298	0,99845906	-0,1640865	-0,7210754
-0,0491222	-0,0016029	-0,1077334	0,74393889	0,0843246	-0,4178032	-0,161715	0,61940603
0,09316421	-0,0615713	0,09373732	-0,6259185	0,0849802	0,29626225	-0,1607355	-0,2033045
0,01117074	0,08956814	0,49917702	1,20601793	0,0928161	0,21599465	-0,1630903	-0,1927058
-0,0083688	0,01887058	0,84539352	0,38051054	0,1086869	-0,5671969	-0,1705206	0,41854539
-0,1288616	0,00852836	1,09632581	0,77878453	0,1326648	0,4890488	-0,1844626	0,04694798
-0,0217909	-0,0567665	1,23161298	-0,2303129	0,1640838	0,17807703	-0,2059661	-0,6078316
-0,0219327	0,01740271	1,24679692	0,42616033	0,2016327	-0,0574905	-0,2356358	0,57060561
0,02509749	-0,0219327	1,15167014	0,03071881	0,2434826	0,12604706	-0,2735981	-9,245E-06
0,05651405	0,02509749	0,96725791	0,54076342	0,2874385	0,19205	-0,3194928	
0,01328761	0,05651405	0,72198133	0,1294023	0,3311015	0,19436391	-0,3724883	
-0,0230307	0,01328761	0,44754245	0,15521314	0,3720316	-0,504213	-0,4313187	
0,04834535	-0,0230307	0,1750125	0,47686774	0,4079014	0,50619909	-0,4943398	
0,05545643	0,04834535	-0,0684889	-0,059844	0,4366335	0,01452959	-0,559601	
0,00165225	0,05545643	-0,2622555	0,71963326	0,4565163	0,99234142	-0,6249296	
0,01665909	0,00165225	0,10476183	-0,6683285	0,4662925	-0,7002358	-0,6880229	
0,06429438	0,01665909	1,1101613	1,27282011	0,4652193	0,34656494	-0,7465452	
0,04446823	0,06429438	1,66819042	0,83046508	0,4530988	0,22628963	-0,7982244	
-0,0035406	0,04446823	1,77924272	0,67493509	0,4302795	-0,5979572	-0,8409461	
0,00653617	-0,0035406	1,52217245	-0,211161	0,3976297	0,48070893	-0,8728398	
0,04184222	0,00653617	1,0202446	0,44259957	0,3564874	0,02305452	-0,892356	
0,02502027	0,04184222	0,41023057	0,01822447	0,3085881	0,77290481	-0,8983297	
-0,011894	0,02502027	-0,1820216	0,54590973	0,2559771	-0,20781	-0,8900299	
0,00854617	-0,011894	-0,658091	0,12088564	0,2009090	0,27886898	-0,8671926	

0,04686228	0,00854617	-0,9555456	0,17580043	0,1457407	0,2095483	-0,8300355
0,00945626	0,04686228	-1,0495309	0,45785499	0,0928220	-0,556956	-0,7792564
-0,0553065	0,00945626	-1,2791625	-0,0192847	0,0443890	0,4922484	-0,7160132
-0,0277659	-0,0553065	-1,2383207	0,74199958	0,0024648	0,01927344	-0,6418869
0,02852884	-0,0277659	0,10476183	-0,6278258	-0,0312297	0,45085521	-0,5588301
-0,0169564	0,02852884	1,1101613	1,21091672	-0,0553491	-0,452053	-0,469101
-0,0301436	-0,0169564	1,66819042	0,07233562	-0,0689809	0,30614037	-0,3751868
0,08064358	-0,0301436	1,77924272	0,78102296	-0,0716831	0,21694713	-0,2797171
0,02029831	0,08064358	1,52217245	-0,2252263	-0,0635016	-0,5736475	-0,1853728
-0,0393515	0,02029831	1,0202446	0,4270718	-0,0449668	0,48746753	-0,0947912
-0,0787335	-0,0393515	0,41023057	0,02931034	-0,0170695	-1,2136492	-0,0104715
-0,0461097	-0,0787335	-0,1820216	0,54098083	0,0187822	1,40067369	0,06531605
-0,1968854	-0,0461097	-0,658091	0,12833202	0,0608239	-0,3990644	0,13061439
0,1417817	-0,1968854	-0,9555456	0,15817313	0,1070106	0,33830802	0,18385456
-0,007657	0,1417817	-1,0495309	0,47399355	0,1551053	0,21925662	0,22391823
0,02964846	-0,007657	-0,9489358	-0,0530582	0,2027757	-0,5930093	0,25018564
-0,0215653	0,02964846	-0,688922	0,72375386	0,2476961	0,48280678	0,26256697
0,01401932	-0,0215653	-0,3215799	-0,6611884	0,2876503	-0,2974536	0,26151568
0,07699961	0,01401932	0,09373732	1,26158915	0,3206317	1,70467114	0,24802268
0,01792272	0,07699961	0,49917702	0,40027545	0,3449362	-0,4731438	0,22359108
-0,0077195	0,01792272	0,84539352	0,93483187	0,3592446	0,32156493	0,19019162
0,06360786	-0,0077195	1,09632581	-0,2413037	0,3626903	0,21996089	0,15019958
0,07725177	0,06360786	1,23161298	0,41333497	0,3549104	-0,582315	0,10631456
0,00479691	0,07725177	1,24679692	0,03941418	0,3360758	0,48510573	0,06146513
-0,0129291	0,00479691	1,15167014	0,53704836	0,3069010	0,02160179	0,01870102
0,04371238	-0,0129291	0,96725791	0,13503247	0,2686298		-0,0189242
0,04775077	0,04371238	0,72198133	0,14192243	0,2229983		-0,0484761
-0,0129799	0,04775077	0,44754245	0,48899858	0,1721753		-0,0672646
-0,0131099	-0,0129799	0,1750125	-0,0853365	0,1186805		-0,0729664
0,04764547	-0,0131099	-0,0684889	0,70576006	0,0652841		-0,0637406
0,02477063	0,04764547	-0,2622555	-0,693526	0,0148900		-0,0383329
-0,0679098	0,02477063	-0,393452	1,31105579	-0,0295939		0,00383589
-0,049536	-0,0679098	-0,4575441	0,00533178	-0,0653927		0,06260231
0,03975983	-0,049536	-0,4577853	0,76591995	-0,0900045		0,13701632
-0,0121609	0,03975983	-0,4039246	-0,2351873	-0,1013379		0,22532563
-0,0491222	-0,0121609	-0,3103609	0,42658809	-0,0978406		0,32499063
0,09316421	-0,0491222	-0,1939997	0,0314871	-0,0786125		0,43273214
0,01117074	0,09316421	-0,0720625	0,54097085	-0,0434994		0,5446132
-0,0083688	0,01117074	0,03990933	0,13014027	0,0068416		0,65615502
-0,1288616	-0,0083688	0,12967033	0,15282657	0,0709070		0,7624859
-0,0217909	-0,1288616	0,18937011	0,4793146	0,1463494		0,85852082
0,00906411	-0,0217909	0,21605616	-0,0661159	0,2300191		0,93916797
0,16257154	-0,0219327	0,21158642	0,71557632	0,3180480		0,99955674

0,05653629	0,02509749	0,18199491	-0,6752284	0,4059768	1,03528076
-0,0023835	0,05651405	0,13641646	1,28380662	0,4889237	1,04264758
-0,0097955	0,01328761	0,08572629	0,92585921	0,5617922	1,0189254
0,04907467	-0,0230307	0,04104543	0,73757876	0,6195143	0,96257616
0,04603809	0,04834535	0,01228605	-0,2097712	0,6573193	0,87346262
0,00700771	0,05545643	0,00691353	0,44747174	0,6710218	0,75301683
0,02547736	0,00165225	0,02902097	0,01429531	0,6573153	0,60435617
0,05873198	0,01665909	0,07885874	0,54817457	0,6140584	0,43233356
0,03582763	0,06429438	0,15282392	0,11781778	0,5405380	0,24350822
-0,0005317	0,04446823	0,24390649	0,18303278	0,4376922	0,19419006
0,01205664	-0,0035406	0,34258983	0,45116428	0,3082729	0,1836126
0,03723409	0,00653617	0,43801366	-0,0056555	0,1569312	0,17824894
0,01815661	0,04184222	0,51937861	0,74907538	-0,0097957	0,1672343
-0,0090017	0,02502027	0,5773062	-0,6143135	-0,1836126	0,1569312
0,01429735	-0,011894	0,60513549	1,19051783	-0,3547272	0,1417817
0,0440245	0,00854617	0,59983371	0,75596466	-0,5122527	0,12047615
0,00535842	0,04686228	0,56258778	0,53072154	-0,6447633	0,10377366
-0,0497184	0,00945626	0,49882153	-0,2061203	-0,7409971	0,089373
-0,0218601	-0,0553065	0,41770222	0,46802298	-0,7907010	0,07275568
0,02469427	-0,0277659	0,33115092	0,0026983	-0,7855909	0,02047615
-0,0188118	0,02852884	0,25237812	0,55473044	-0,7203923	-0,0325366
-0,0271617	-0,0169564	0,19419006	0,11068106	-0,5939027	-0,0793377
0,07275568	-0,0301436	0,1672343	0,19825011	-0,4099967	-0,0920835
0,02047615	0,08064358	0,17824894	0,43791673	-0,1784671	-0,2082729
-0,0325366	0,02029831	0,22881585	0,01913315	0,0844380	-0,2288158
-0,0793377	-0,0393515	0,31453299	0,76078137	0,3559580	-0,2523781
-0,0920835	-0,0787335	0,42513326	-0,591593	0,6074647	-0,3082729
0,1417817	-0,0461097	0,54511908	1,15746141	0,8060810	-0,3547272
-0,007657	-0,1968854	0,65552419	0,3269836	0,9176035	-0,3723409
0,02964846	0,1417817	0,73631128	0,96519252	0,9111268	-0,4099967
-0,0215653	-0,007657	0,7691747	-0,2327026	0,7658426	-0,5939027
0,01401932	0,02964846	0,74076178	0,40743137	0,4805731	-0,6447633
0,07699961	-0,0215653	0,64551236	0,04107876	0,0866960	-0,7353037
0,01792272	0,01401932	0,48802093	0,53476651	-0,3347754	-0,7334622
-0,0077195	0,07699961	0,21425999	0,13571917	-0,6310673	-0,7316206
0,06360786	0,01792272	-0,0595009	0,14192596	-0,5494533	-0,7297791
-0,0325366	-0,0077195	-0,0399093	0,48835095	0,2476961	-0,7279376
-0,0793377	0,06360786	-0,0720625	-0,0809485	0,2876503	-0,7260961
-0,0920835	0,07725177	-0,1296703	0,70991686	0,3206317	-0,7242546
0,1417817	0,00479691	-0,1893701	-0,6874032	0,3449362	-0,7176165
-0,007657	-0,0129291	-0,2160562	1,30032266	0,3592446	-0,6270163
0,02964846	0,04371238	-0,2115864	0,40027358	0,3626903	-0,4740404
-0,0215653	0,04775077	-0,1819949		0,3549104	-0,4765596

-0,0325366	-0,0129799	-0,1364165	0,3360758	-0,4169609
-0,0793377	-0,0131099	-0,0857263	0,3069010	-0,3573622
-0,0920835	0,04764547	-0,0410454	0,2686298	-0,2977634
0,1417817	0,02477063	-0,012286	0,2229983	-0,2381647
-0,007657	-0,0679098	-0,0069135	0,1721753	-0,1503038